Biological Criteria for Wadeable/Perennial Streams of Missouri

February 2002

Missouri Department
of Natural Resources

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ACKNOWLEDGEMENTS

The U.S. Environmental Protection Agency provided significant funding for this project. The information for this project was provided by the Missouri Department of Natural Resources, the University of Missouri – Columbia, and the Missouri Resource Assessment Partnership.

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We would like to thank the following people for providing a review of this document:

Tom Wilton – Iowa Department of Natural Resources, Pat Costello – U.S. EPA Region VII, Gary Welker – U.S. EPA Region VII, Dr. John Havel – Southwest Missouri State University, Dr. Stefan Cairns – Cenrtal Missouri State University, Michael T. Barbour – Tetra Tech, Inc., Susan Jackson – U.S. EPA Office of Science and Technology, and Chris Yoder – Midwest Biodiversity Institute.

EXECUTIVE SUMMARY

The Federal Clean Water Quality Act Amendments of 1972 codified the concept of “biological integrity” as the condition of an aquatic community inhabiting an unimpaired water body. The law profoundly affected water management by mandating that the condition of the aquatic life residing in streams and rivers is an endpoint to be measured. The perspective began to change from concentrating on what enters a stream or river to the well being of human health and the resident aquatic life. States are encouraged to develop numeric or narrative biological criteria for their waterways to describe biological integrity. In Missouri the narrative portion of biological criteria was established in the 1994 revision of the Water Quality Standards. Using the general guidance of the United States Environmental Protection Agency (**U. S. EPA**), the Missouri Department of Natural Resources (**hereafter referred to as “department” or “the department”**) and the University of Missouri – Columbia have been researching and developing a systematic biological criteria framework for the wadeable streams of Missouri since 1992. Numeric biological criteria are being developed for benthic macroinvertebrates because of their long history of use as sentinels of biological integrity and their importance to stream ecosystems.

The Missouri Department of Natural Resources’ primary intended uses of stream assessments using biological criteria are:

- To establish regional attainment goals within Missouri that are relevant to aquatic life use and resource protection.

- To serve as a scientifically valid benchmark for monitoring the effectiveness of best management practices and stream restoration.

- To provide a sound scientific basis for evaluating condition status and changes over time in water quality, as reflected by the aquatic community.

Developing Biological Criteria involved the following components:

1. Aquatic Ecoregions of Missouri

Ecoregions are geographical regions of the state with somewhat homogenous environmental conditions and fauna. The goal in selecting ecological regions for biological criteria development is to have a sufficient number of regions that contain similar fauna, yet not so many that the system becomes unmanageable. The regionalization scheme that has the most justification for biological criteria using aquatic macroinvertebrates is a part of the hierarchical aquatic classification system developed by the Missouri Resource Assessment Partnership (**MoRAP**). The ecological regions most appropriate for wadeable/perennial streams are Ecological Drainage Units (**EDU**), available as MoRAP map series 2001-001 (Figure 1). This framework has been developed using landscape components as well as analyses using aquatic organisms.

2. Reference Streams

An important assumption underlying the use of biological criteria to assess biological integrity is that least impacted streams have a naturally functioning fauna representative of an ecological region. The process of biological criteria development involves determining biological attributes of “reference conditions” that reflect integrity, then using these attributes as a standard to which all other sites and streams can be compared. Reference streams were selected by reviewing the Missouri Water Atlas (1986) and department maps to identify perennial sections of all wadeable streams in the state. A list of candidate streams was developed based on watershed size and location. A step-wise process involving examination of human

disturbance, stream size, stream channel morphology and condition, and migration barriers was then conducted as well as obtaining input from the department's Water Pollution Control Program and Missouri Department of Conservation fisheries biologists. A total of 62 reference stream segments have been proposed for the next revision to the Missouri Water Quality Standards.

3. Survey of the Habitat and Biota

To insure valid and comparable data, Project Procedures and Standard Operating Procedures have been developed for different aspects of stream assessment. Sampling and processing of macroinvertebrates is addressed in the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (Missouri Department of Natural Resources 2001a). A standardized level of identification for macroinvertebrates is addressed in the Taxonomic Levels for Macroinvertebrate Identifications Standard Operating Procedure (Missouri Department of Natural Resources 2001b). Habitat analysis is addressed in the Stream Habitat Assessment Project Procedure (Missouri Department of Natural Resources 2000). These procedures are available through the Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program, Water Quality Monitoring Section, P.O. Box 176, Jefferson City, Missouri 65102. Data have been collected using these procedures and stored in an electronic database at the department since 1994.

4. Biological Metrics

For the purpose of biological criteria development, a metric is defined as biological measures of stream health that change in response to the environmental condition of a stream. Each measure indicates something about the biotic community, which is related to stream health, at the individual, population, or community level. Several measures are often combined to integrate biological response to perturbation and to provide a system to monitor and assess stream health. Eleven such measures were selected for initial evaluation of their potential to show a variety of structural and functional responses. Four metrics were selected for inclusion in a multiple metric index after conducting analyses for variability, sensitivity, and redundancy (Rabeni et al. 1997). The metrics are Taxa Richness (**TR**); Ephemeroptera, Plecoptera, Trichoptera Taxa (**EPTT**); Biotic Index (**BI**); and the Shannon Diversity Index (**SDI**).

5. Framework for Numeric Biological Criteria

Reference stream metric data are organized by Ecological Drainage Unit and season (spring and fall). In addition, the streams are classified as riffle/pool (**RP**) or glide/pool (**GP**) stream types and cold water (**CW**) or warm water (**WW**) temperature regimes. Numeric criteria are calculated for both spring and fall seasons for the following classifications:

Ozark/Current/ Black Drainage-RP/WW
Ozark/Current/ Black Drainage-RP/CW
Ozark/Gasconade Drainage-RP/WW
Ozark/Gasconade Drainage-RP/CW
Ozark/Upper St. Francis/Castor Drainage-RP/WW
Ozark/Meramac Drainage-RP/WW
Ozark/Mississippi Tributaries between Missouri and Ohio Rivers-RP/WW
Ozark/Moreau/Loutre Drainage-RP/WW
Ozark/Moreau/Loutre Drainage-GP/WW
Ozark/Elk/Spring Drainage-RP/WW
Ozark/Elk/Spring Drainage-RP/CW
Ozark/Osage Drainage-RP/WW
Ozark/Osage Drainage-RP/CW
Ozark/White Drainage-RP/WW
Ozark/White Drainage-RP/CW

Plains/Mississippi Tributaries between Des Moines and Missouri Rivers-GP
Plains/Mississippi Tributaries between Des Moines and Missouri Rivers-RP

Plains/Grand/Chariton Drainage-GP
Plains/Grand/Chariton Drainage-RP
Plains/Missouri Tributaries between Blue and Lamine-GP
Plains/Missouri Tributaries between Blue and Lamine-RP
Plains/Osage Drainage-GP
Plains/Missouri Tributaries between Nishnabotna and Platte-GP

Mississippi Alluvial Plain/Lower Mississippi/St. Johns Bayou Drainage-GP
Mississippi Alluvial Plain/Little Drainage-GP
Mississippi Alluvial Plain/White/Black Drainage-GP

6. Development of Numeric Criteria

The multiple metric index that the department uses is called the Missouri Stream Condition Index (**MSCI**). To make four metrics of different scales equal and comparable, all metric data are normalized to unitless values. To do this a scoring system of 5, 3, or 1 is established as follows for each metric. The lower quartile of the distribution of each metric is calculated from reference streams data in each classification listed in component 5. This point is considered the minimum value representative of unimpaired conditions. For those metrics whose value decreases with increasing impairment (TR, EPTT, and SDI), any value above the lower quartile (25%) of the reference distribution receives the highest score of 5. For the BI, whose value increases with increasing impairment, any value below the upper quartile (75%) of the reference distribution receives the highest score of 5. The remainder of each metrics potential range below the lower quartile is bisected and scored either a 3 or a 1. Each of the four metrics can receive a maximum score of 5, which dictates a total potential score of 20. Every category in the framework has numeric criteria that are calculated specifically for that category.

7. Numeric Criteria for Wadeable/Perennial Streams and Rivers

There are three levels of stream condition, Fully Biologically Supporting (**FBS**), Partially Biologically Supporting (**PBS**), and Non-Biologically Supporting (**NBS**). A reference sites MSCI typically scores $\geq$16, so scores of 16-20 were selected as FBS. Sites that were known to be impaired and were tested had a median MSCI score of 10, thus scores of 10-14 were designated as PBS. Scores of 4-8 were designated as NBS. The categories of PBS and NBS are considered to be impaired and not meeting the beneficial use of Protection of Aquatic Life as stated in the Missouri Water Quality Standards.

INTRODUCTION

The goal of this document is to communicate the development of biological criteria for wadeable, perennial streams, and small rivers of Missouri. Biological criteria development has its roots in the concept of biological integrity, which was first explicitly included in water resource legislation in the Water Pollution Control Act Amendments of 1972 (Public Law 92-500). The concept of biological integrity was retained in subsequent revisions of that act which are now an integral component of water resource programs at state and federal levels (U.S. Environmental Protection Agency 1990).

The goal of biological integrity encompasses all factors affecting ecosystems. Biological integrity is defined (Karr and Dudley 1981) as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region." This simply means that a stream with high biological integrity will have little or no influence from humans. Biological criteria are measures of biological integrity as a narrative description and/or numerical values that describe the reference aquatic communities inhabiting waters that have been given a designated aquatic life use. Besides the inherent objective of the protection of aquatic biological communities, the possible uses of biological criteria by the department include:

- To establish regional attainment goals within Missouri that are relevant to aquatic life use and resource protection.

- To serve as a scientifically valid benchmark for monitoring the effectiveness of best management practices and stream restoration.

- To provide a sound scientific basis for evaluating condition status and changes over time in water quality, as reflected by the aquatic community.

Biological criteria development in Missouri began with a grant provided to Dr. Charles Rabeni, Missouri Cooperative Fish and Wildlife Unit, University of Missouri, Columbia. This initial project began in 1992 and finished in 1997 with a final report to the department (Rabeni et al. 1997). Macroinvertebrates were selected as the first component of the aquatic community for which biological criteria would be developed. U.S. EPA guidance has been followed throughout the development of biological criteria in Missouri and the following publications have proved to be valuable:

- Biological Criteria: National Program Guidance for Surface Waters
  EPA-440/5-90-004 April 1990 (U.S. Environmental Protection Agency 1990)

- Biological Criteria: Guide to Technical Literature
  EPA-440/5-91-004 July 1991 (U.S. Environmental Protection Agency 1991a)

- Biological Criteria: Research and Regulation
  EPA-440/5-91-005 July 1991 (U.S. Environmental Protection Agency 1991b)

- Biological Criteria: State Development and Implementation Efforts
  EPA-440/5-91-003 July 1991 (U.S. Environmental Protection Agency 1991c)

- Biological Assessment Methods, Biocriteria, and Biological Indicators
  EPA 230-B-96-001 February 1996 (U.S. Environmental Protection Agency 1996a)

- Summary of State Biological Assessment Programs for Streams and Rivers EPA 230-R-96-007
  February 1996 (U.S. Environmental Protection Agency 1996b)

- Biological Criteria: Technical Guidance for Streams and Small Rivers
  EPA 822-B-96-001 May 1996 (U.S. Environmental Protection Agency 1996c)

Since 1994, the department's Air and Land Protection Division (**ALPD**), Environmental Services Program (**ESP**), Water Quality Monitoring Section (**WQMS**) has taken the lead within the agency in the continued development of biological criteria. The biological database is housed at the department's ESP, WQMS with data available by request to the database manager (Stuart Harlan).

Successful implementation of biological criteria requires a systematic program to collect and evaluate complex scientific information and translate that information in a manner that can be understood by many. The primary steps for development and implementation of biological criteria are introduced here and either discussed in greater detail in later sections of this document or references are provided to publications whereby more detailed information can be found. The primary steps for development of biological criteria were: the establishment of a framework through ecological region designation and selection of reference streams within a classification system, standardized biological sampling and stream habitat assessment procedures, metrics selection and calibration, and numeric criteria calculation to fit the established framework.

AQUATIC ECOREGIONS OF MISSOURI

Importance of Classification to Biomonitoring

Biomonitoring relies on a comparative approach where biological conditions at monitoring sites are compared to criteria established at relatively high-quality reference sites. The accuracy and validity of such comparisons is dependent upon investigators ensuring that reference criteria are only applied to monitoring sites expected to develop relatively similar biological communities under natural conditions. Failure to do so could lead to “false positives” (impairment exists when it really does not) or “false negatives” (no impairment exists when in fact it does) (Cairns and Smith 1994). A classification system is needed that accounts for inherent natural variation among sampling locations and groups these locations into classes within which valid comparisons can be made.

Classifying Stream Ecosystems

Inherent natural variation among two or more monitoring locations is the result of a complex array of environmental factors operating at numerous spatio-temporal scales. As a result, most investigators advocate a hierarchical approach to stream classification (Warren 1979, Lotspeich and Platts 1982, Frissel et al. 1986, Hawkins et al. 1993). Hierarchical systems recognize that smaller systems develop within the constraints imposed by the larger systems of which they are part (Frissel et al. 1986, Maxwell et al. 1995). This nested relationship is very useful for classifying and mapping ecosystems at multiple levels and provides the necessary framework for stratified sampling (Maxwell et al. 1995).

There are essentially two approaches to developing hierarchical classification frameworks. *A posteriori* , or bottom up approaches, utilize actual field data and usually employ multivariate statistical methods to group locations with similar structural or functional patterns into distinct classes. Biological or physical habitat data from numerous sites can be used to statistically group locations with similar patterns, first into habitat unit classes (e.g. riffles, pools, glides), then similar habitat units into stream segment classes (e.g. headwater, creek, small river, large river), and then similar combinations of stream segments into watershed classes, etc. This approach is very data and time intensive. Also, this approach is not suitable in highly altered landscapes when the purpose of the classification system is to distinguish locations based upon differences in natural potential (e.g. community composition). *A priori*, or top down classification, utilizes existing scientific information and theory to subdivide the landscape into smaller units, which are assumed to have similar structural and functional patterns. A criticism of this approach is that it is subjective and, therefore, observer dependent. Despite the differences in approaches, the objectives of both are the definition of classes such that variation within a class is less than variation between classes. Considering the advantages and limitations of both approaches, Gauch (1982) advocates a complimentary approach, utilizing both methods.

An Aquatic Ecological Unit Classification for Missouri

Several national, regional, and state classification systems have been developed which subdivided Missouri’s landscape into distinct ecoregional units (Fennemann 1928, Bennitt and Nagel 1937, Thom and Wilson 1980, Omernik 1987, Bailey 1995). The ecoregions delineated by these various classification systems are based largely on differences in climate, geology, soils, landform, and vegetation. Although the character of stream ecosystems is largely determined by terrestrial landscape (Lyons 1989; Bryce and Clarke 1996), none of these classification systems is sufficient for describing the distribution and distinctiveness of freshwater communities (Abell et al. 2000). These classification systems fail to account for the prominent role that isolation plays in shaping freshwater communities as the natural distribution of many aquatic organisms are determined by drainage boundaries and patterns (Pflieger 1989). As a result, watersheds often cross one or more of these “terrestrial” ecoregions. This presents another problem in that the character of a specific stream segment, and its component habitats, is the product of all the ecoregions draining to it and not just the one in which it resides. For these and other reasons there is a need for a separate set of aquatic ecoregions that more accurately accounts for biophysical patterns observed in stream ecosystems (Pflieger 1989, Maxwell et al. 1995, Abell et al. 2000).

In 1989, Pflieger published the first aquatic community classification system for Missouri. This *a posteriori* classification system utilized over 50 years of fish and crayfish collection data from Missouri streams to statistically define 4 aquatic faunal regions, 12 faunal divisions, and 4 or more stream types (largely based on stream size) for each division. In 1995, Maxwell and others published a hierarchical classification framework for aquatic ecological units in North America. This *a priori* classification utilized fish distribution data and expert opinion to define and map the first four of eleven levels in the overall hierarchy (e.g. Zone, Subzone, Region, Subregion). This classification actually complements Pflieger's classification system by providing broader ecoregional units that are useful in placing Missouri's stream ecosystems into a national or even global context.

Recently, as part of the Missouri Aquatic Gap Analysis Project, the MoRAP developed a classification hierarchy for defining aquatic ecological units for Missouri. There are 8 hierarchical levels in this classification system that describe riverine ecosystems according to natural physical and biological factors. The levels in the hierarchy are as follows: Zone; Subzone; Region; Subregion; Ecological Drainage Unit (EDU); Aquatic Ecological System; Valley Segment Type; and Habitat Unit. For each level, aquatic ecosystems with distinct biophysical potentials are defined and mapped using Geographic Information Systems (**GIS**) technologies. This classification system also incorporates distribution data for fish, mussels, crayfish, and snails into delineation of ecological units making it an iterative combination of the two classification approaches described above. In the most basic sense, the MoRAP classification hierarchy actually combines and improves upon the classification system developed by Pflieger (1989) and Maxwell et al. (1995) by incorporating additional data and additional classification procedures from several other stream classification frameworks (Frissell et al. 1986, Seelbach et al. 1997, Higgins et al. 1999).

Macroinvertebrates were the first aquatic community component researched during the initial development of biological criteria for wadeable/perennial streams. During the development it became obvious that a classification framework was needed that decreased variability but was not overly complicated. Rabeni and Doisy (2000) utilized data from the biocriteria project that helped address the appropriate aquatic ecological region level. Until the MoRAP classification system is completed and validated it seems that the appropriate level for the development of wadeable/perennial stream biocriteria is Ecological Drainage Units. While the use of the Aquatic Ecological System level may further reduce variability in the biological community, the smaller size of these areas makes it difficult to find a sufficient number of reference streams to characterize the aquatic community in a statistically sound manner.

The MoRAP map series 2001-001 (Figure 1) shows the names, approximate size, and location of the Missouri EDUs. Although there are 19 Missouri Ecological Drainage Units, only 17 contain potential reference stream miles in Missouri sufficient to develop biological criteria. These EDUs form the base level of the framework for biological criteria.

The Missouri Ecological Drainage Units are:

Ozark/ Current/ Black Drainage
Ozark/ Gasconade Drainage
Ozark/ Upper St. Francis/ Castor Drainage
Ozark/ Meramac Drainage
Ozark/ Mississippi Tributaries between Missouri and Ohio Rivers
Ozark/ Moreau/ Loutre Drainage
Ozark/ Elk/ Spring Drainage
Ozark/ Osage Drainage
Ozark/ White Drainage

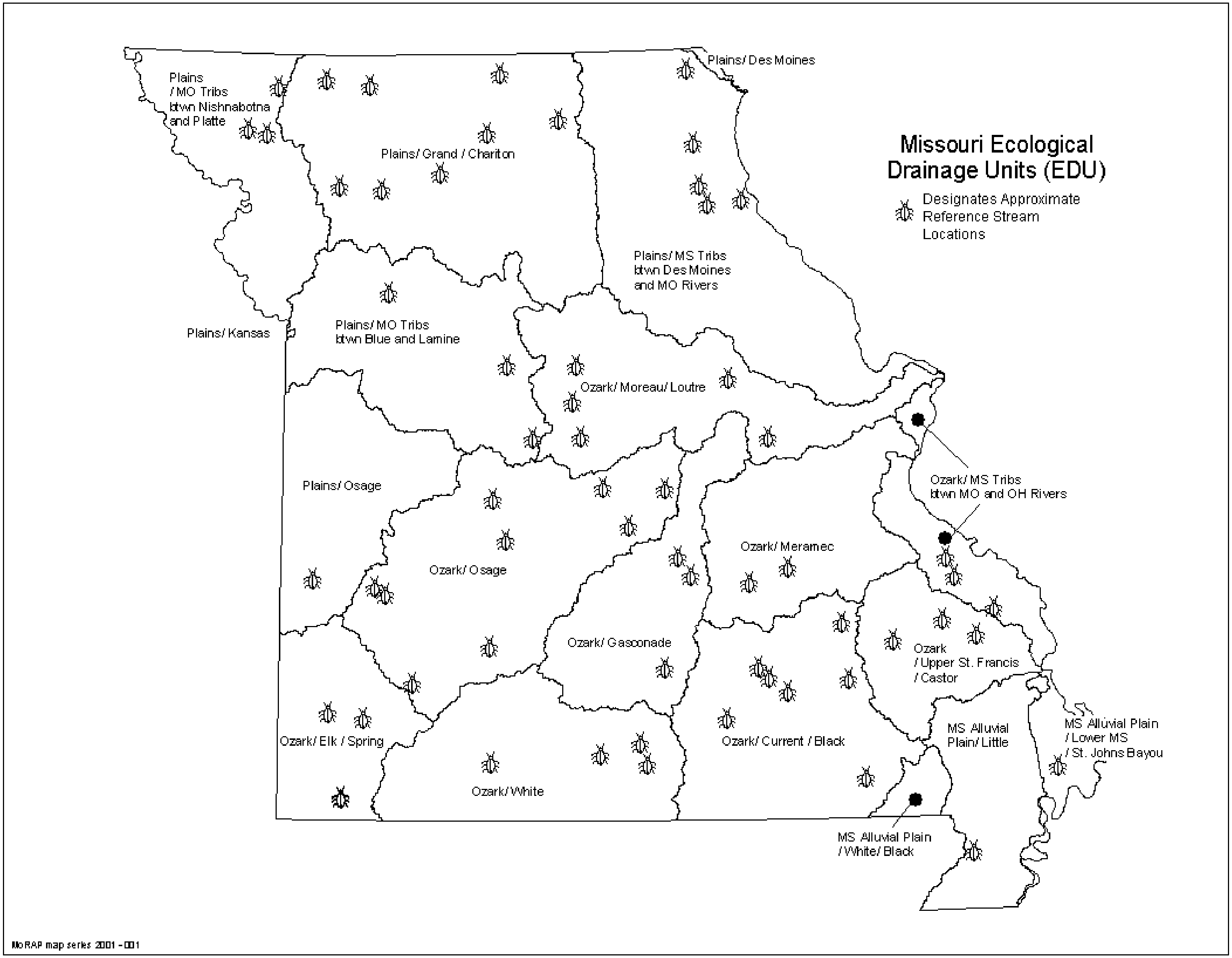
Plains/ Mississippi Tributaries between Des Moines and Missouri Rivers
Plains/ Grand/ Chariton Drainage
Plains/ Missouri Tributaries between Blue and Lamine Rivers
Plains/ Osage Drainage
Plains/ Missouri Tributaries between Nishnabotna and Platte Rivers

Plains/ Des Moines Drainage
Plains/ Kansas Drainage

Mississippi Alluvial Plain/ Lower Mississippi/ St. Johns Bayou Drainage
Mississippi Alluvial Plain/ Little Drainage
Mississippi Alluvial Plain/ White/ Black Drainage

.

Figure 1
Missouri Ecological Drainage Units with Reference Locations



REFERENCE STREAMS

Introduction

Development of biological criteria requires establishment of reference conditions. Reference conditions describe characteristics of waterbodies least impaired by anthropogenic activities and are used to define attainable habitat and biological conditions. Reference conditions are the standard by which impairment is judged.

To establish regional reference conditions, a set of streams of similar type and size are identified in each aquatic region. These streams must represent similar habitat types, be representative of the ecoregion, and exhibit biological integrity. Biological criteria can then be developed and used to assess impacted surface waters in the same region.

Method for Establishing the Reference Condition

Table 1 describes a process for selecting reference sites for rivers and streams as described by Hughes et al. (1986). If properly chosen these sites may serve as references for a larger number of similar streams.

Table 1
Steps in Determining Candidate Reference Streams and Rivers

1. Evaluate human disturbance	Eliminate watersheds with concentrations of human influence, point source pollution, channelization or atypical sources of pollution (e.g. acidification, mine waste, overgrazing, clearcuts).
2. Evaluate stream size	Use watershed area and mean annual discharge instead of stream order. Watershed areas and discharges of impacted and reference sites should differ by less than an order of magnitude.
3. Evaluate stream channel	Locate influent streams, springs and lakes; determine drainage pattern, stream gradient, and distance from major receiving water. Retain the stream type most typical of the region.
4. Locate refuges	Unless the refuge results from local natural features atypical of the region, consider parks, monuments, wildlife refuges, natural areas, state and federal forest, grasslands and wilderness areas.
5. Determine migration barriers, historical connections among streams, and known zoogeographical patterns	Such information helps to form reasonable expectations of species presence and richness.
6. Suggest reference sites	Reject degraded or atypical watersheds and rank candidates by level of disturbance.

A candidate list of reference streams is developed by a process where all possible streams are grouped by size using broad classification categories and evaluated for human disturbance. The starting point was the Missouri Water Atlas (Missouri Department of Natural Resources 1986) and Missouri Water Quality Standards (1996), which were used to identify all rivers and streams that are considered permanent (Class P) or that contain permanent pools (Class C). The size range of interest was achieved by the elimination of large rivers. The general size class of interest is labeled as wadeable/perennial. The rationale for selecting this size of stream or river to begin the development of biological criteria is attributed to the desire that conditions be assessable by foot and provide the best advantage for demonstrating ecoregional patterns. Although there is no agreement on the best way to describe stream size (stream order, drainage area, miles to headwater, drainage area/unit discharge, etc.), there is agreement that streams and rivers can be grouped into headwater, major tributary, and large river. Macroinvertebrate species richness and density have been demonstrated to be higher in major tributaries (Crunkilton and Duchrow 1991, Harrel and Dorris 1968, Minshall et al. 1985) and have a greater potential for showing spatial difference. Predictable change in structure and function of stream ecosystems occurs along a longitudinal gradient from headwater to large river (Vannote et al. 1980, Wiley et al. 1990). The fact that major tributaries are often wadeable, perennial, and best able to demonstrate ecoregional patterns, is support for narrowing the focus of reference stream selection to this general category for the first round of biological criteria development.

The six-step selection process of Hughes et al., as described in Table 1, provides a flexible and consistent method of evaluating reference suitability. Topographic maps, water quality staff at the Missouri Department of Natural Resources and the Missouri Department of Conservation (**MDC**), and Fisheries Management Biologists at MDC were consulted during steps 1, 3, 4, and 5 of the reference stream selection process. Water quality violations and fish kill reports were examined to help in the process.

Field verification for accessibility to the site and the determination of minimal disturbance was performed as part of the final selection process. Examples of indicators of good quality streams include: 1) extensive, old, and natural riparian vegetation; 2) relatively high heterogeneity in channel width and depth; 3) abundant large woody debris, coarse bottom substrate, or extensive aquatic or overhanging vegetation; 4) a discharge that varies normally with no evidence of flow control or excessive water removal; 5) relatively clear water with natural color and odor; 6) abundant diatom, insect, and fish assemblages; and 7) the presence of piscivorous birds and mammals.

Out of 92 candidate reference streams, 63 were initially field verified for minimal impact. The remaining 29 were placed on an alternate list to be examined as time and budget permitted. These initial 63 streams were ranked and 45 were chosen for the preliminary round of sampling. The 18 streams that were not selected from the initial 63 were placed on the alternate list. Part of the ranking process included the comparison of drainage area (Table 1, Step 2). Reference stream segments had drainage areas which differed by less than an order of magnitude. The drainage area of Ozark streams ranged from 24 to 219 square miles, while the drainage area of Plains streams ranged from 38 to 376 square miles.

In 1994, the original 45 reference streams were placed in the Missouri Water Quality Standards (1996). Since that time 17 of the alternates have been evaluated, sampled, and proposed for the 2002 revision of the Water Quality Standards. Figure 1 shows reference stream distribution by Ecological Drainage Unit.

Reference Stream Information

Appendix A provides location and general information concerning each reference stream. The following gives a brief explanation of column heading found in Appendix A. Legal coordinates only represent general bounds in which the stream is considered to be a biocriteria reference segment and they are not meant to represent exact points of transition from reference to non-reference conditions.

Waterbody:

> Waterbody names are the naming convention used in the Missouri Water Quality Standards -10 CSR 20-7.0 (Missouri Department of Natural Resources 1996).

County:

> The county name listed is the county that contains the majority of the reference stream segment.

Downstream Legal:

> The downstream legal field contains the legal coordinates of the downstream end of the reference stream reach.

Upstream Legal:

The upstream legal field contains the legal coordinates of the upstream end of the reference stream reach.

11 Digit Hydrologic Unit:

The 11 Digit Hydrologic Unit contains the majority of the reference stream reach. The U.S. Geological Survey establishes this numbering convention.

Drainage Area – Square Miles:

The square miles of drainage area are average values calculated from the approximate mid-range of the reference reach.

Ecological Drainage Unit:

Ecological Drainage Units are discussed in Chapter 2 (Aquatic Ecoregions of Missouri) and are designated by the Missouri Resource Assessment Partnership (Missouri Resources Assessment Partnership 2001).

Sampling Regime:

Sampling regimes represent stream types and affect multi-habitat sampling. Two different types of sampling regimes are designated. Streams that are dominated by riffle/pool sequences have multi-habitat sampling regimes composed of slightly different multiple-habitats than streams that are dominated by glide/pool sequences. The sampling regime is explained further in Chapter 4 (Survey of Habitat and Biota).

Temperature Regime:

Temperature regimes represent water temperature categories that can be found in the Missouri Water Quality Standards -10 CSR 20-7.0 (Missouri Department of Natural Resources 1996). Reference stream segments that fall within sections of Streams Designated for Cold-Water Fishery (Table C) are listed as cold water. All others are listed as warm water. Temperature has a profound effect upon biological communities and is incorporated as a level of stream classification.

Land Cover (11 Digit / EDU):

The land cover data were derived from Thematic Mapper satellite data from 1991, 1992, and 1993 and interpreted by MoRAP. Land cover was calculated for the 11 digit Hydrologic Unit that contained drainage upstream of the reference section. Land cover was also calculated for the Ecological Drainage Unit for comparative purposes. Land cover categories were merged for the following: Urban = class 1 & class 2; Grassland = class 5 & class 6; Forest = class 8-13; Swamp and Marsh = class 14 & class 15. Class 3 (Barren or sparsely vegetated) was eliminated. The actual coverage and documentation is available on the department's GIS server or through MoRAP.

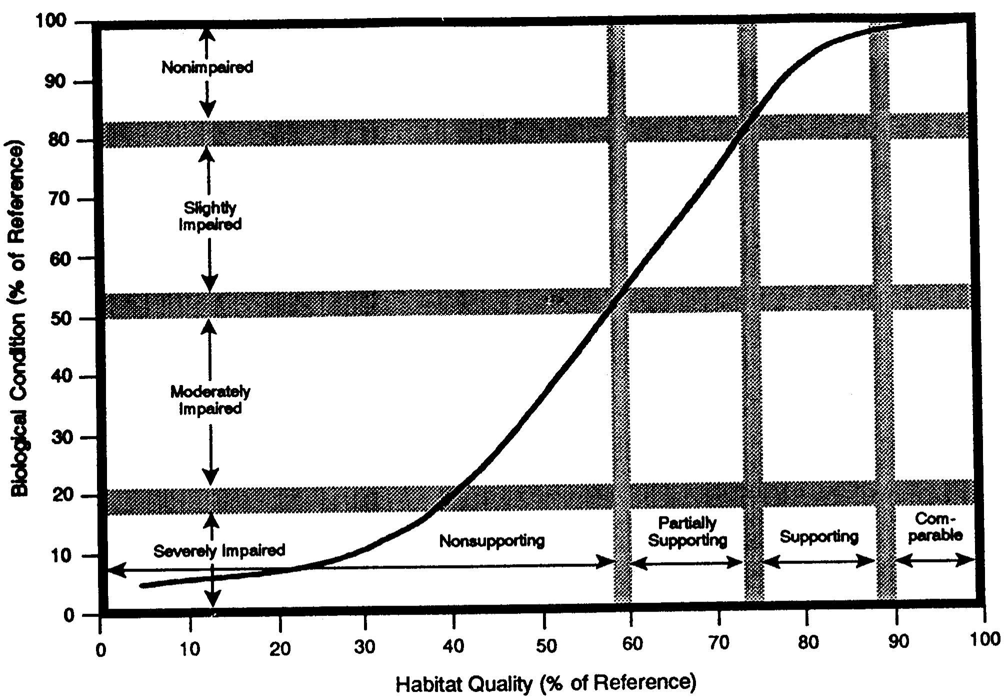
SURVEY OF HABITAT AND BIOTA

Introduction

One goal of the Clean Water Act is the protection of biological integrity. Much of the focus for biological assessments has been on water quality. However, if the goal is evaluating biological integrity, then habitat may be important to factor in as a potential impairment. Habitat assessments allow an understanding of the relation between habitat quality and biological conditions. Such assessments identify obvious constraints on the attainable potential of the site, assists in selection of appropriate sampling stations, and provides basic information for interpreting biological survey results (Barbour and Stribling 1991).

Because stream conditions vary considerably across an ecological region, the investigator must make a decision whether the habitat quality of a study site is comparable to the habitat quality of reference conditions. A conceptual relation between habitat quality and biological condition is shown in Figure 2 (Barbour and Stribling 1991). This relationship demonstrates that habitat can range from 0 to 100% of the reference. In theory, there is also a point on this range at which the habitat quality could be considered not able to support a biological community equivalent to reference conditions. The orientation of the relationship line between habitat quality and biological condition is not fixed and in different regions of Missouri may differ in the degree of linearity, slope, and y-intercept. Additional research is needed to determine the relationship of habitat quality and biological condition in Missouri streams. Until research is completed, the total score from the physical habitat assessment of the study site is expected to be from 75% to 100% similar to the appropriate class of reference condition in order to fully support a comparable biological condition.

Figure 2
Relationship Between Habitat Quality and Biological Condition
Barbour and Stribling 1991



Temporary habitat assessment categories are as follows:

1) Comparable to Reference	$\geq$90%
2) Supporting	75-89%
3) Partially Supporting	60-74%
4) Non-supporting	<59%

Stream Reach Considerations

All macroinvertebrate sampling and habitat assessment is conducted in a stream reach approximately twenty times the average width of the stream. The average width of a stream is determined by randomly selecting five cross section transects. At each transect the width of the stream at the top of the lower bank is measured. See Section H (Lower Bank Channel Capacity) of the Stream Habitat Assessment Project Procedure (2000) for determination of the lower bank.

In Rabeni et al. (1999), multiple reaches of stream, each twenty times the stream width, were compared to identify the adequacy of the sampling reach. In only 6% of the possible cases was the coefficient of variation for any metric reduced by >10% by sampling additional reaches. Results concluded that a single, well-chosen reach is adequate for sampling macroinvertebrate communities and, depending on the potential impairment, a single reach can be representative of an entire stream segment. If more accuracy is needed, two comparable reaches within three stream miles of each other will be sampled to characterize the aquatic community.

Habitat Assessment

Before a biological assessment is completed it is important to conduct a standardized habitat assessment. Missouri streams can be divided into two basic types: riffle/pool or glide/pool prevalence. Since streams have different biological sampling regimes different habitat assessment procedures are required. The Stream Habitat Assessment Project Procedure (2000) is available through the Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program, Water Quality Monitoring Section, P.O. Box 176, Jefferson City, MO 65102.

The basis of stream habitat assessment lies in the measurement of quantitative and qualitative features that are recorded on the Physical Characterization/Water Quality Data Form and the Worksheet for Riffle/Pool or Glide/Pool Habitat Assessment Forms. The information collected is then used to score ten habitat parameters on the Riffle/Pool Habitat Assessment Form or the Glide/Pool Habitat Assessment Form.

This habitat assessment procedure is a modified version of the scoring matrix for Riffle/Run Prevalence or Glide/Pool Prevalence found in the USEPA Rapid Assessment Protocols for Use in Wadeable Streams and Rivers (Barbour et al. 1999). We have modified the EPA assessment protocol to increase the precision and to better reflect the conditions in Missouri. Whereas some habitat assessments are designed to provide trend data, the habitat assessments performed by the department are used within an EDU on a season by season basis and are used to support biological assessments. This habitat assessment procedure is not intended as a stand-alone product for problem identification nor is it intended for trend analysis.

Parameters scored using the Riffle/Pool prevalence include:

1) Epifaunal substrate/available cover
2) Embeddedness
3) Velocity/depth regime
4) Sediment deposition
5) Channel flow status
6) Channel alteration
7) Riffle quality
8) Bank stability
9) Vegetative protection

10) Riparian vegetative zone width

Parameters scored using the Glide/Pool prevalence include:

1) Epifaunal substrate/available cover
2) Pool substrate characterization
3) Pool variability
4) Sediment deposition
5) Channel flow status
6) Channel alteration
7) Channel sinuosity
8) Bank stability
9) Vegetative protection
10) Riparian vegetative zone width

Latitude/longitude coordinates, discharge measurements, and water chemistry parameters (temperature, specific conductance, pH, dissolved oxygen, chloride, nitrate + nitrite – nitrogen, ammonia, and phosphorus) are typically sampled at study sites in addition to habitat assessment

Although the procedure outlined in the Stream Habitat Assessment Project Procedure is repeatable and purportedly evaluates a variety of potential stressors of the biota, its usefulness is limited (Rabeni 2000). The Missouri Department of Natural Resources and the MDC have entered into a memorandum of understanding to undertake a cooperative biological and habitat assessment program. Part of this agreement identifies the need to standardize and improve habitat assessment procedures between agencies. Ongoing research will be evaluated during the next several years to refine relationships between habitat and biota and to develop an improved habitat assessment procedure.

Biological Assessments

The department's multi-habitat sampling method (Missouri Department of Natural Resources 2001a) is designed for permanent flowing, wadeable streams. Wadeable streams are defined as having an average depth less than 1.5 meters. If necessary these sampling procedures can be adapted for use in the accessible, shallow portions of larger streams. Sampling should be done only when flow and depth conditions do not impair the ability of the investigator to efficiently collect organisms from the major habitats or do not threaten the safety of the individual. Ideally, sampling efforts should be carried out during periods of stable base flow before peak emergence of aquatic insects. In Missouri the sampling periods, which correspond to biological criteria framework categories, are from mid-March through mid-April (Spring) and from mid-September through mid-October (Fall).

For the purpose of this document, Missouri has two stream types:

1) Streams with RP predominance are primarily found in the Ozark aquatic region of Missouri but are also found in some portions of the Prairie region. A characteristic feature of a riffle/pool stream type is repeated and regular occurrence of riffles. Riffles typically form every 7-10 stream widths (Hynes 1970). The three predominant habitats sampled in riffle/pool streams are: a) flowing water over coarse substrate (riffles/runs); b) non-flowing water over depositional substrate (pools); and c) rootmat substrate.

2) Streams with GP predominance are primarily found in the Prairie and Mississippi Alluvial Plains aquatic regions of Missouri. Glide/pool stream types generally have a repeated and predictable meander sequence. Pools typically form immediately after a bend. The three predominant habitats sampled in glide/pool streams are: a) non-flowing water over depositional substrate (pools); b) large woody debris substrate; and c) rootmat substrate.

Macroinvertebrates from most habitats are collected by using an aquatic kick net with 500-micron mesh netting. Each habitat requires a slightly different collecting technique. Macroinvertebrates found on large woody debris substrate are collected with a 500-micron mesh bag made of nitex. Samples are preserved in the field and processed in the laboratory by sub-sampling to standard target numbers. Once organisms are sub-sampled they are generally identified to genus or species.

Details of macroinvertebrate sampling, laboratory processing, data processing, data analysis, and quality control can be found in the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (Missouri Department of Natural Resources 2001a). Details of macroinvertebrate taxonomic identification and biotic index values can be found in the Standard Operating Procedure MDNR-WQMS-209, Taxonomic Levels for Macroinvertebrate Identifications (Missouri Department of Natural Resources 2001b).

Both documents are available through the Missouri Department of Natural Resources, Air and Land Protection Division, Environmental Services Program, Water Quality Monitoring Section, P.O. Box 176, Jefferson City, Missouri 65102.

BIOLOGICAL METRICS

Eight metrics were proposed for macroinvertebrate community analysis in the Environmental Protection Agency's Rapid Bioassessment Protocol (Plafkin et al. 1989). Barbour et al. (1992) evaluated these eight metrics and others for redundancy and variability. Results from their evaluation suggested that the most reliable metrics are Taxa Richness, EPT Taxa, and Biotic Indices. Additional metric research conducted within Missouri by Rabeni et al. (1997) independently confirmed Taxa Richness, EPT Taxa, and the Biotic Index, as well as the Shannon Diversity Index, as the most reliable and sensitive. These are the four primary metrics used to derive scoring criteria.

Primary Metrics:
1. Taxa Richness (TR)
2. Ephemeroptera/Plecoptera/Trichoptera Taxa Index (EPTT)
3. Biotic Index (BI)
4. Shannon Diversity Index (SDI)

It is an important to note that all metrics are dependent upon taxonomic resolution. When performing taxonomic identifications for use with biological criteria, adherence must be kept with the Taxonomic Levels of Identification Standard Operating Procedure (Missouri Department of Natural Resources 2001b).

Taxa Richness (TR)

Taxa Richness reflects the health of the community through a measurement of the number of taxa present. In general, the total number of taxa increases with improving water quality, habitat diversity, and/or habitat suitability. Taxa Richness is calculated by counting all taxa from the sample. A taxon is defined as the lowest identifiable level in the Linnaean hierarchical taxonomic classification system as listed in the Taxonomic Levels for Macroinvertebrate Identification Standard Operating Procedure (Missouri Department of Natural Resources 2001).

Ephemeroptera/Plecoptera/Trichoptera Index (EPTT)

The EPTT index is the total number of distinct taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera (Missouri Department of Natural Resources 2001b). The EPTT index generally increases with increasing stream health. This value summarizes taxa richness within the insect orders that are considered to be pollution sensitive. The EPTT Index is calculated by counting EPT taxa from the sample.

Biotic Index (BI)

The biotic index quantifies the invertebrate community as to its overall tolerance to organic pollution by summing tolerances of individual taxon. The biotic index was first developed by Chutter (1972) and then modified for Wisconsin by Hilsenhoff (1977). The Hilsenhoff Biotic Index was developed as a means of detecting organic pollution in communities inhabiting rock or gravel riffles of Wisconsin streams. Hilsenhoff later reported changes and further modifications (Hilsenhoff 1982, Hilsenhoff 1987).

Many modifications have been made to the Hilsenhoff Biotic Index since it's inception. Most biotic indices continue to base tolerance values for each taxon on a range from 0 to 10, with higher values indicating increased tolerance. The overall pollution tolerance of the macroinvertebrate community is expressed as a single value between 0 and 10. The major sources of modifications are adjustments to the tolerance values assigned to each taxon. These adjustments have become necessary as the biotic index is developed for different geographical areas because each tolerance value is based upon data from a gradient of organically polluted conditions. A tolerance value sometimes needs regional adjustments when it has been determined for an organism that is rare or at the edge of its range. In addition, new tolerance values are needed as new taxa are encountered.

Biotic Index values to be used for the calculation of this metric can be found in the Standard Operating Procedure MDNR-WQMS-209 (Missouri Department of Natural Resources 2001b). Tolerance values specific to Missouri are under development. In the interim, tolerance values for the department's Biotic

Index are primarily based upon North Carolina (Lenat 1993) because the values were assigned using the most repeatable methods. If values for Missouri taxa cannot be found from Lenat (1993) then values are used from Wisconsin (Hilsenhoff 1987), New York (Bode et al. 1988) or Kansas (Huggins and Moffett 1988).
The formula for calculating the Biotic Index is:

$$BI = \sum_{i=1}^{n} \frac{X_i T_i}{n}$$

Where: X_i = number of individuals within each species
T_i = tolerance value of that species
n = total number of organisms in the sample

Shannon Diversity Index (SDI)

The Shannon Diversity Index is a measure of community composition which takes into account both richness and evenness. The SDI is based upon a formula presented in a book by Shannon and Weaver (1949). Some confusion exists because the original theory was developed simultaneously by Shannon (Shannon and Weaver 1949) and Wiener (1948) at approximately the same time and is often called the Shannon-Wiener Diversity Index. The original formula (Shannon and Weaver 1949) is based upon log base 10, but has commonly been modified to log base e (Peet 1974). Regardless of the log base used, consistency is an important concern. The department uses the name Shannon Diversity Index because a modified formula (log base e) is used and because of past confusion in the appropriate historical name.

Ecologists commonly make the following assumptions concerning diversity: 1) a more diverse community is a healthier community; 2) diversity increases as the number of taxa increase; 3) and as the distribution of individuals among those taxa should be evenly distributed.

The formula for calculating the Shannon Diversity Index is:

$$H' = -\sum_{i=1}^{n} (p_i)(\log_e p_1)$$

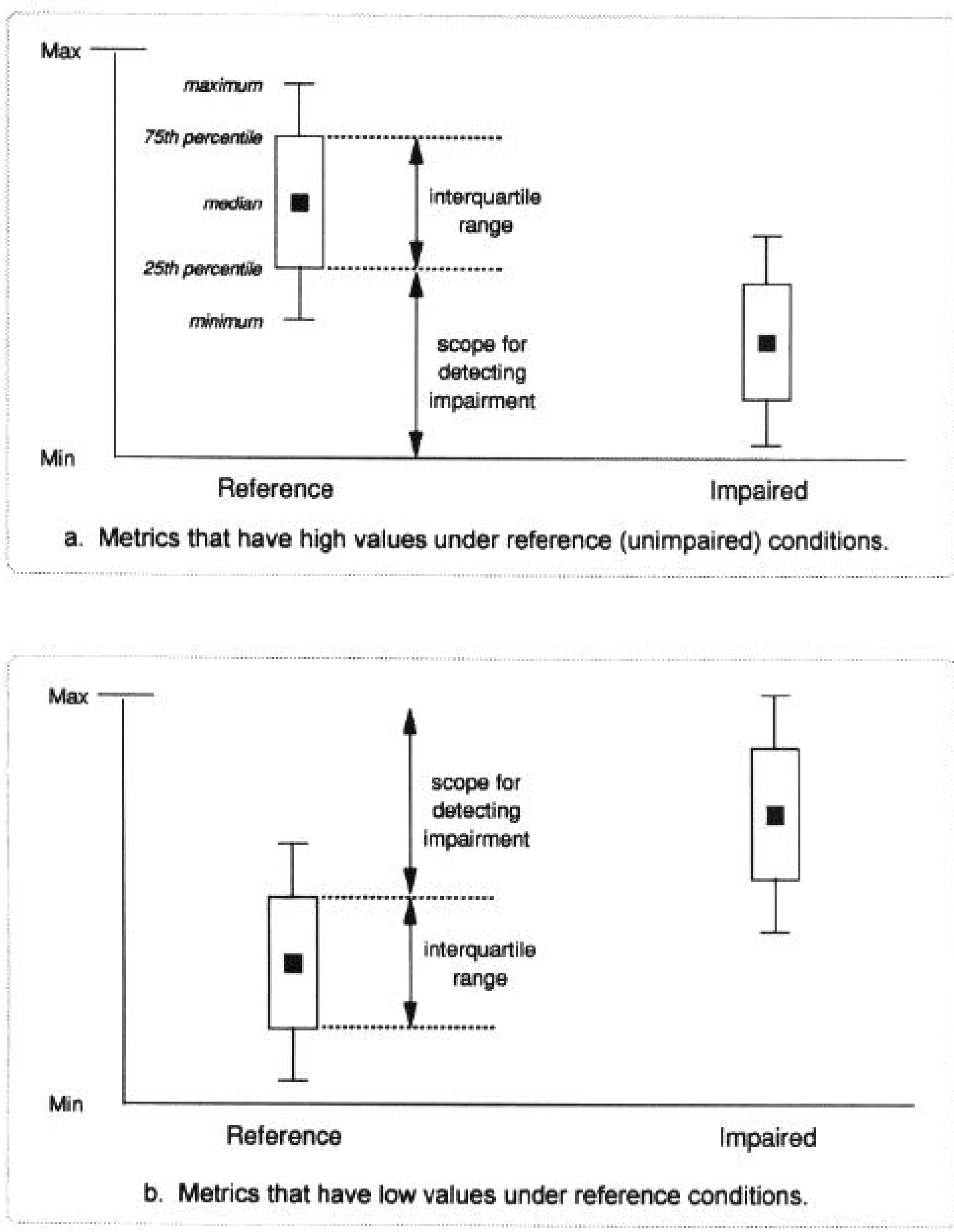
Where: *H¢* = Information content of sample (= index of diversity)
n = Number of species
p_i = Proportion of total sample belonging to ith species

Metric Sensitivity

Although metric sensitivity was analyzed by Rabeni et al. (1997), the detection coefficient concept was not explored. Therefore, opportunity is taken at this time to further support the ability of the selected metrics to assess impairment to streams.

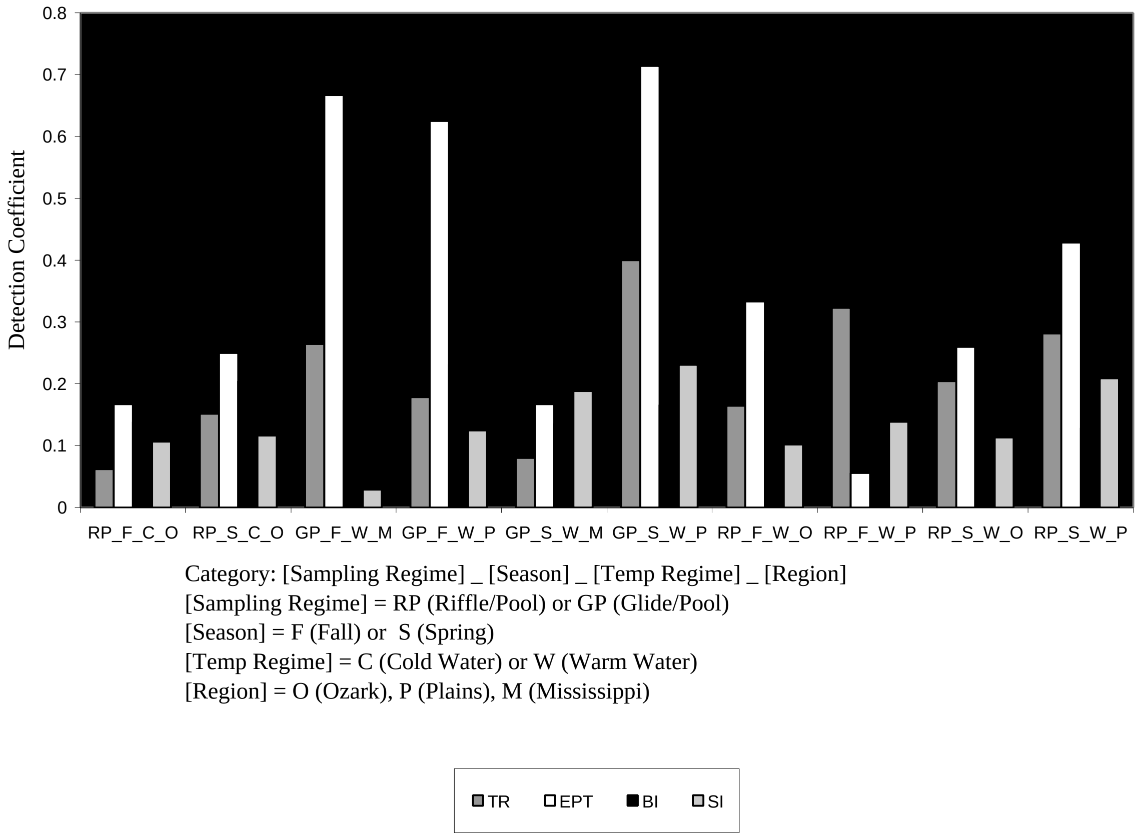
A key analysis method for evaluating the strength of metrics to detect impairment is accomplished by calculating a metric detection coefficient. The coefficient is calculated by dividing the interquartile range of a metric for reference conditions by the remainder of the range available to that metric (U.S. Environmental Protection Agency 1996c). Figure 3 (Illustration of Metric Detection Coefficient) graphically displays the concept using box-and-whisker plots. This figure demonstrates a central point, which is the median value of the variable; the box shows the 25th and 75th percentiles (interquartile range); and the whiskers show the minimum to maximum values (range). Box-and-whisker plots are simple, straightforward, and powerful in determining whether a particular metric is a good candidate for use in assessment. When calculating the detection coefficient for potential metrics, high variability (scope of detection) compared to the range of response should be used with caution. Taxa richness, EPT taxa, and the Shannon Index decrease in value with increased impairment and the detection coefficient for reference sites is thus a good measure of the metrics' potential discrimination ability (Figure 4). The scope for detection would be from the 25th percentile to the minimum value. The Biotic Index is designed to increase in value under impaired conditions, and the scope for detection would be from the 75th percentile to the maximum value (Figure 3).

Figure 3
Illustration of Metric Detection Coefficient



The metric detection coefficients for reference data collected by the department are shown as Figure 4 (Detection Coefficients for Wadeable/Perennial Missouri Reference Streams). Because the biological metrics used are general purpose, the detection coefficients are calculated for the larger ecological regions of Missouri (Ozarks, Plains, and Mississippi Alluvial Plain). As can be observed from Figure 4, most detection coefficients are below a 0.3 ratio. The EPTT is not as sensitive and slightly less useful in the Plains and Mississippi Alluvial Plain, but is still a very good overall metric.

Figure 4
Detection Coefficients for Wadeable/Perennial Missouri Reference Streams
Data from 1994-2000



Category: [Sampling Regime] _ [Season] _ [Temp Regime] _ [Region]
[Sampling Regime] = RP (Riffle/Pool) or GP (Glide/Pool)
[Season] = F (Fall) or S (Spring)
[Temp Regime] = C (Cold Water) or W (Warm Water)
[Region] = O (Ozark), P (Plains), M (Mississippi)

FRAMEWORK FOR NUMERIC BIOLOGICAL CRITERIA

Reference stream metric data are organized by Ecological Drainage Unit and season (Spring or Fall). In addition the streams are classified by Sampling Regime [e.g. Riffle/pool or Glide/pool dominated], and Temperature Regime [e.g. Cold Water or Warm Water dominated]. All potential categories are listed in Table 2. Where reference conditions are available, Table 2 provides the numeric biological criteria categories for both spring and fall seasons. If no reference condition exists or not enough data exists, it is documented in the table. Only the categories for which biological criteria are available are listed in Appendix B.

In Table 2, NA is placed in the column labeled Reference Condition Not Available, to designate that reference conditions were not found for a potential category. The two potential reasons why reference conditions are listed as not available are: 1) the potential category in the framework does not exist; or 2) the category is present in low abundance and there are no minimally impaired streams segments.

There are five categories for which the numeric criteria category exists but minimum reference data are not available (listed below). Minimum data must be represented by three data values for the calculation of the 25^{th} percentile or at least two available reference streams per EDU. The five categories with insufficient data for numeric criteria calculation will be combined with the most ecologically similar EDU(s). Those criteria will then be shared among all combined EDUs. The column in Table 2, labeled Exception Categories For Criteria, and the following comments (1-5), provide details concerning categories that were combined.

1) Data from the Ozark/Gasconade Drainage RP/WW category will be combined with the Ozark/Osage Drainage RP/WW category
2) Data from the Ozark/White Drainage RP/CW category will be combined with the Ozark/Gasconade Drainage RP/CW category
3) Data from the Plains/Missouri Tributaries between Blue and Lamine Drainage GP/WW category will be combined with the Plains/Osage Drainage GP/WW category
4) Data from the Plains/Missouri Tributaries between Blue and Lamine Drainage RP/ WW category will be combined with the Ozark/Moreau/Loutre Drainage RP/WW category
5) Data from the Mississippi Alluvial Plain/Little GP/WW, Mississippi Alluvial Plain/Lower Mississippi/ St. Johns Bayou GP/WW, Mississippi Alluvial Plain/White/Black categories will be combined

Table 2
Framework for Numeric Biological Criteria

Ecological Region	Ecological Drainage Unit	Sampling Regime	Temp. Regime	Criteria available =Y	Reference Condition Not Available =NA	Exception Categories For Criteria (*)
Ozark	Current/Black Drainage	RP	WW	Y		
Ozark	Current/Black Drainage	RP	CW		NA	
Ozark	Current/Black Drainage	GP	WW		NA	
Ozark	Current/Black Drainage	GP	CW		NA	
Ozark	Gasconade Drainage	RP	WW	Y		(C)(1)
Ozark	Gasconade Drainage	RP	CW	Y		(2)
Ozark	Gasconade Drainage	GP	WW		NA	
Ozark	Gasconade Drainage	GP	CW		NA	
Ozark	Moreau/Loutre Drainage	RP	WW	Y		(4)
Ozark	Moreau/Loutre Drainage	RP	CW		NA	
Ozark	Moreau/Loutre Drainage	GP	WW	Y		
Ozark	Moreau/Loutre Drainage	GP	CW		NA	
Ozark	Upper St. Francis/Castor Drainage	RP	WW	Y		
Ozark	Upper St. Francis/Castor Drainage	RP	CW		NA	

Ecological Region	Ecological Drainage Unit	Sampling Regime	Temp. Regime	Criteria available =Y	Reference Condition not available =NA	Exception Categories For Criteria (*)
Ozark	Upper St. Francis/Castor Drainage	GP	WW		NA	
Ozark	Upper St. Francis/Castor Drainage	GP	CW		NA	
Ozark	Meramac Drainage	RP	WW	Y		
Ozark	Meramac Drainage	RP	CW		NA	
Ozark	Meramac Drainage	GP	WW		NA	
Ozark	Meramac Drainage	GP	CW		NA	
Ozark	Mississippi Tributaries between Missouri and Ohio Rivers	RP	WW	Y		
Ozark	Mississippi Tributaries between Missouri and Ohio Rivers	RP	CW		NA	
Ozark	Mississippi Tributaries between Missouri and Ohio Rivers	GP	WW		NA	
Ozark	Mississippi Tributaries between Missouri and Ohio Rivers	GP	CW		NA	
Ozark	Elk/Spring Drainage	RP	WW	Y		
Ozark	Elk/Spring Drainage	RP	CW	Y		
Ozark	Elk/Spring Drainage	GP	WW		NA	
Ozark	Elk/Spring Drainage	GP	CW		NA	
Ozark	Osage Drainage	RP	WW	Y		
Ozark	Osage Drainage	RP	CW	Y		(1)
Ozark	Osage Drainage	GP	WW		NA	
Ozark	Osage Drainage	GP	CW		NA	
Ozark	White Drainage	RP	WW	Y		
Ozark	White Drainage	RP	CW	Y		(C)(2)
Ozark	White Drainage	GP	WW		NA	
Ozark	White Drainage	GP	CW		NA	
Plains	Mississippi Tributaries between Des Moines and Missouri Rivers	RP	WW	Y		
Plains	Mississippi Tributaries between Des Moines and Missouri Rivers	RP	CW		NA	
Plains	Mississippi Tributaries between Des Moines and Missouri Rivers	GP	WW	Y		
Plains	Mississippi Tributaries between Des Moines and Missouri Rivers	GP	CW		NA	
Plains	Grand/Chariton Drainage	RP	WW	Y		
Plains	Grand/Chariton Drainage	RP	CW		NA	
Plains	Grand/Chariton Drainage	GP	WW	Y		
Plains	Grand/Chariton Drainage	GP	CW		NA	
Plains	Missouri Tributaries between Blue and Lamine	RP	WW	Y		(C)(4)
Plains	Missouri Tributaries between Blue and Lamine	RP	CW		NA	
Plains	Missouri Tributaries between Blue and Lamine	GP	WW	Y		(C)(3)
Plains	Missouri Tributaries between Blue and Lamine	GP	CW		NA	
Plains	Osage Drainage	RP	WW		NA	
Plains	Osage Drainage	RP	CW		NA	
Plains	Osage Drainage	GP	WW	Y		(3)
Ecological Region	Ecological Drainage Unit	Sampling Regime	Temp. Regime	Criteria available	Reference Condition	Exception Categories

				=Y	not available =NA	For Criteria (*)
Plains	Osage Drainage	GP	CW		NA	
Plains	Missouri Tributaries between Nishnabotna and Platte	RP	WW		NA	
Plains	Missouri Tributaries between Nishnabotna and Platte	RP	CW		NA	
Plains	Missouri Tributaries between Nishnabotna and Platte	GP	WW	Y		
Plains	Missouri Tributaries between Nishnabotna and Platte	GP	CW		NA	
Mississippi Alluvial Plain	Lower Mississippi/St. Johns Bayou Drainage	RP	WW		NA	
Mississippi Alluvial Plain	Lower Mississippi/St. Johns Bayou Drainage	RP	CW		NA	
Mississippi Alluvial Plain	Lower Mississippi/St. Johns Bayou Drainage	GP	WW	Y		(C)(5)
Mississippi Alluvial Plain	Lower Mississippi/St. Johns Bayou Drainage	GP	CW		NA	
Mississippi Alluvial Plain	Little Drainage	RP	WW		NA	
Mississippi Alluvial Plain	Little Drainage	RP	CW		NA	
Mississippi Alluvial Plain	Little Drainage	GP	WW	Y		(C)(5)
Mississippi Alluvial Plain	Little Drainage	GP	CW		NA	
Mississippi Alluvial Plain	White/Black Drainage	RP	WW		NA	
Mississippi Alluvial Plain	White/Black Drainage	RP	CW		NA	
Mississippi Alluvial Plain	White/Black Drainage	GP	WW	Y	NA	(C)(5)
Mississippi Alluvial Plain	White/Black Drainage	GP	CW		NA	

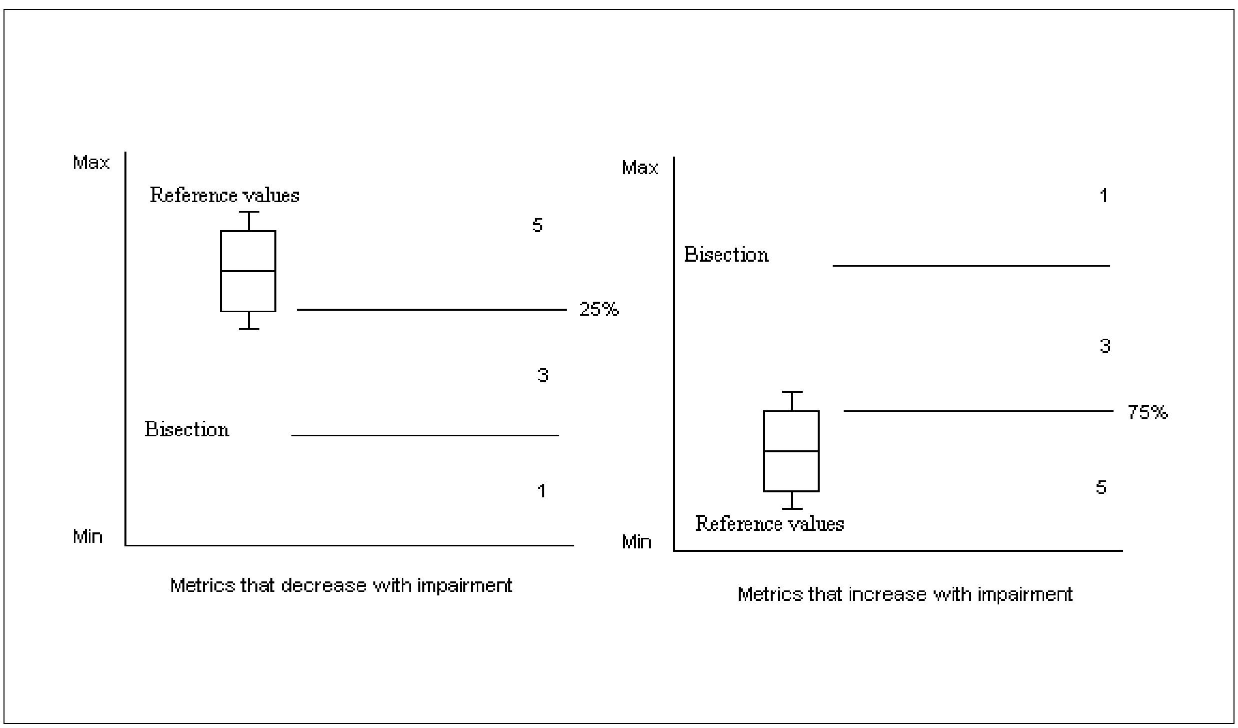
(*) In the Exception Categories for Criteria, a (C) designates that the category did not have minimum data for numeric criteria calculation and was combined with another EDU. The number in parenthesis designates an EDU that will share data to generate criteria. Both the EDU that does not meet the minimum and the EDU that is sharing data will exhibit the same criteria.

DEVELOPMENT OF NUMERIC CRITERIA

Once the classification scheme, reference sites, and metrics have been selected, the task becomes one of designing the actual criterion. A variety of choices are available for measuring central tendency. Two general approaches have evolved for the determination of a quantitative regional biocriterion (U.S. Environmental Protection Agency 1996c). The department uses the aggregate approach in which the 25th percentile is calculated for each metric using the data from reference sites. In operational bioassessments, metric values below the lower quartile of reference conditions are typically judged impaired to some degree (U.S. Environmental Protection Agency 1996c, Ohio Environmental Protection Agency 1990, Barbour et al. 1996). Because percentiles do not assume a particular distribution of the data, they have an important advantage over the use of means and standard deviations (or standard errors). Furthermore, outliers do not exert an undue influence over the data as they can on means and standard errors. The establishment of biological criteria for a particular aquatic ecoregion attempts to represent the typical biological community performance, not the outliers and extremes.

The multiple metric index used by the department is called the Missouri Stream Condition Index (MSCI). To make four metrics of different scales equal and comparable, all metric data are normalized to unitless values. These unitless values are established for each metric by using a 5, 3, or 1 scoring system. The lower quartile of the distribution of each metric is calculated from reference stream data in each classification. This point is considered the minimum value representative of unimpaired conditions. For those metrics whose value decreases with increasing impairment (TR, EPTT, and SDI), any value above the lower quartile (25%) of the reference distribution receives the highest score of 5 (see Figure 5). For the BI whose value increases with increasing impairment, any value below the upper quartile (75%) of the reference distribution receives the highest score of 5. The remainder of each metric's potential range below the lower quartile is bisected and scored either a 3 or a 1 (Figure 5). Each of the four metrics can receive a maximum score of 5, which dictates a total potential score of 20.

Figure 5
Stream Condition Index Scoring



NUMERIC CRITERIA FOR WADEABLE/PERENNIAL STREAMS AND RIVERS

The actual values for the 25th percentile and the bisection of the potential range of each metric are listed for each category of the framework in Appendix B (Missouri Biocriteria Wadeable/Perennial 25th Percentile and Range Bisection Values). Some consistency is needed to turn a set of values for a particular category into scoring criteria. The rules (illustrated in Figure 5) are as follows:

- Greater than (>) the quartile value is scored 5
- Less than or equal (≤) to the quartile value and greater than or equal to (≥) the bisection value is scored 3
- Less than (<) the bisection value is scored 1

Once the biological community of a study stream reach is scored, the data are interpreted to belong to one of three levels of stream condition (Table 3): Fully Biologically Supporting; Partially Biologically Supporting; and Non-Biologically Supporting. A reference sites MSCI typically scores ≥16, and scores of 16-20 were selected as FBS. Sites that were known to be impaired and were tested had a median MSCI score of 10, and scores of 10-14 were designated as PBS. Scores of 4-8 were designated as NBS (Rabeni et al. 1997). Both PBS and NBS are considered to be impaired and do not meet the beneficial use of Protection of Aquatic Life as stated in the Missouri Water Quality Standards.

Table 3
Missouri Stream Condition Index

Rating	MSCI Score
Fully Biologically Supporting (FBS)	16-20
Partially Biologically Supporting (PBS)	10-14
Non-Biologically Supporting (NBS)	4-8

USE OF THE MISSOURI STREAM CONDITION INDEX

Scoring Impaired Conditions

As part of the development of wadeable/perennial stream biological criteria, many sampling stations were selected at stream locations suspected or known to have impairments. Rabeni et al. (1997) used a small dataset of impaired streams to calibrate and document the function of metrics and the function of the Missouri Stream Condition Index. In addition, since 1994 the department has sampled at 100 known or potentially impaired locations. The combined data from both spring and fall seasons are scored by impairment categories in Table 4 (Scoring Data). The categories are locations used for the numeric biological criteria development (BIOREF), and the general impairment categories of channelization (CHAN), sediment contamination from heavy metals (METALS), non-point source (NPS), and point source (PS). There is also a category that includes streams that have been used as controls in studies but are not considered entirely adequate to serve as biocriteria references (REF).

Table 4
Scoring Data

Impairment Categories	Total_Score	Number of Total Scores
BIOREF	12	9
BIOREF	14	32
BIOREF	16	49
BIOREF	18	84
BIOREF	20	122
CHAN	16	2
CHAN	18	2
METALS	12	2
METALS	16	1
NPS	10	1
NPS	12	2
NPS	14	7
NPS	16	7
NPS	18	7
NPS	20	4
PS	6	3
PS	8	3
PS	10	14
PS	12	7
PS	14	10
PS	16	8
PS	18	3
PS	20	17
REF	14	9
REF	16	14
REF	18	8
REF	20	20

Table 4 lists the impairment categories, the MSCI score in the column labeled Total_Score, and the Number of Total Scores for that scoring category. The Scoring Data Summary (Table 5) provides information concerning the number of locations that would fall below a score of 16 (partially or non-supporting). It is important to note that although the MSCI does assess impaired conditions, the locations monitored were known or suspected to have problems and information in Table 5 should be used with caution concerning generalizations of the overall condition of waters of the state. Although there was considerable variation in the condition among impaired locations, all locations were targeted and do not represent a random sample that could be extrapolated to broad geographic areas.

Although there may be some concern that 14% of reference locations fell below a score of 16, it must also be remembered that the 25th percentile of reference condition was selected as a cut-off for each metric for several reasons. One of those reasons is the problem associated with data collected over a long time period (7 years) and under natural conditions. These data can be expected to exhibit certain variability because of changes in natural conditions; however, some of the natural variability is undesirable. Examples of this would be the effects associated with severe drought or scouring floods. Using the 25th percentile of reference conditions for each metric as a standard for impairment allows undesirable natural variability to be filtered out. It is equally important that this same natural variability be considered when using biological criteria during biological assessments.

Table 5
Data Scoring Summary

Impairment	Total Locations	Number below Score of 16	Percent below Score of 16
BIOREF	296	41	14%
CHAN	4	0	0%
METALS	3	2	66%
NPS	28	10	36%
PS	65	37	57%
REF	51	9	18%

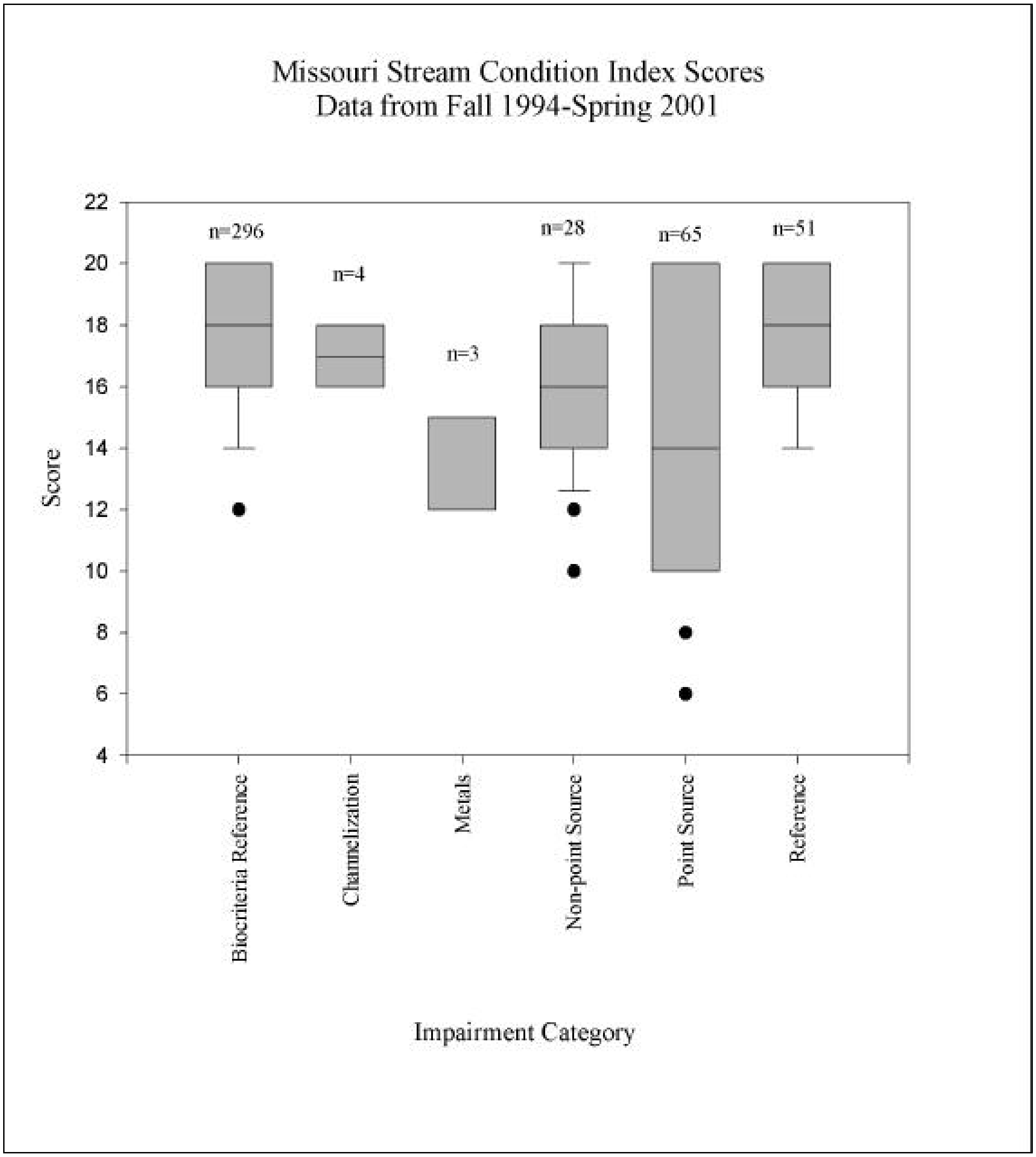
Figure 6 is a graphical representation of biological criteria reference stream scores and impairment categories. These box plots show the median, 25%, 75%, 10%, 90%, and outliers (dark circles). Although there is a range of conditions represented in each category, some generalization can be made. For example, the median levels for metals sample locations and point source locations are below the impairment threshold of 16.

Precision of Scoring

One issue concerning biological data collected under natural conditions is the precision, or repeatability, of the results. To document the repeatability of assessments using biological criteria the department collected a small set of duplicate samples (n=18). A duplicate sample consisted of different investigators collecting samples at the same time within the same stream reach. These samples were then processed and identified by a variety of personnel within the department’s ESP, WQMS. Therefore, duplicate samples incorporate variability associated with both the field and laboratory.

The duplicate samples were analyzed for quality control purposes, which includes information such as quantitative taxa similarity (see Missouri Department of Natural Resources 2001a for further explanation) and the average difference of each metric (Table 6). The greater concern was whether duplicate MSCI scores change categories. Using the score of <16 as a benchmark for impairment, the scores from duplicates changed categories in only 5.5% of the cases (1 out of 18), at the Middle Fabius River. These data suggest that sampling results are repeatable to the same impairment category 95% of the time that a team of trained department biologists performs a biological assessment using biological criteria methods.

Figure 6



Missouri Stream Condition Index Scores
Data from Fall 1994-Spring 2001
Score
22
20
18
16
14
12
10
8
6
4
n=296
n=4
n=3
n=28
n=65
n=51
Biocriteria Reference
Channelization
Metals
Non-point Source
Point Source
Reference
Impairment Category

Table 6
Duplicate Sample Data

Waterbody	Sample Number	Duplicate Sample Number	Quantitative Taxa Similarity	*Delta Taxa Richness	*Delta EPT	*Delta BI	*Delta SI	Score for Sample Number	Score for Duplicate Sample Number
Little Niangua R	95-0877	95-0878	72.44	2	3	0.42	0.11	20	20
Bear Ck	95-0886	95-0887	81.02	1	2	0.27	0.24	16	16
West Piney Ck	96-0813	96-0814	81.96	7	1	0.42	0.05	20	20
Sinking Ck	99-4507	99-4508	81.42	5	5	0.06	0.27	20	18
Middle Fabius R	99-4562	99-4563	77.44	2	1	0.11	0.01	20	20
East Fork Crooked R	99-4527	99-4528	79.13	0	2	0.42	0.09	20	18
River Aux Vases	00-10150	00-10151	80.75	1	2	0.12	0.03	20	20
Deer Ck	00-10109	00-10110	77.90	3	5	0.02	0.01	20	20
East Fork Grand R	00-10114	00-10115	80.36	4	1	0.23	0.01	18	16
South R	00-10160	00-10161	79.95	3	1	0.2	0.24	20	18
Middle Fabius R	00-10164	00-10165	75.71	2	3	0.48	0.29	14	18
White Cloud Ck	00-10117	00-10118	72.66	5	2	0.24	0.16	20	18
Maple Slough Ditch	00-10138	00-10139	65.54	9	5	0.18	0.08	18	16
Center Ck	00-10131	00-10132	66.55	5	2	0.67	0.01	18	20
Marble Ck	01-19522	01-19523	73.58	1	2	0.23	0.06	20	20
Little Maries R	01-19527	01-19528	77.32	6	5	0.15	0	18	18
Meramec R	01-19508	01-19509	71.35	1	5	0.14	0.01	20	18
Little Fox R	01-19519	01-19520	85.75	0	2	0.22	0.1	14	12
Average			76.71	3	3	0.25	0.1		

*Delta = the difference between the sample and the duplicate sample metric

Accuracy of Scoring

In addition to repeatability, the issue of accuracy is an additional objective in scientific studies. Accuracy is commonly defined as the closeness of a measured value to its true value and is dependent on having a good measuring device or system. The difficulty in dealing with the accurate assessment of biological communities centers on the ability to know what the true value is before you sample it. To truly know if the SCI places biological communities accurately requires that we measure known impaired communities. The only way to know whether a stream has impairment with some certainty is to specify criteria that are far from the natural conditions that should support a natural or minimally impaired biological community. To do this, the department selected a set of 10 wadeable/perennial streams that had abnormal chemical and physical water chemistry properties. These streams have municipal point source contributions that result in effluent dominating the stream at least during part of every year and effluent dominance of the stream provides the impairment criteria for the 10-stream data set. Effluent dominance was calculated by dividing the (7)–day Q_{10} by the design flow or actual flow. Table 7 lists the stream name, the water body identification number, the (7)-day Q_{10} of the stream, water quality problems as listed on the 303d list, name of the facility, the design flow for the wastewater treatment plant in cubic feet/second, the actual average flow of the wastewater treatment plant in cubic feet/ (when known), and the % effluent of the stream below the discharge. The (7)-day Q_{10} is defined as the average minimum flow for seven (7) consecutive days that has a probable recurrence of once-in-ten (10) years.

Biological collections were made using established methods and the SCI scores were calculated for the effluent dominated streams. All biological sampling locations were within 3 miles of the discharge of the point source, with no major change in the flow conditions between the point source and the sampling location. SCI scores are listed for each stream in Table 8 and are from department data between 1996-2001. Of the 31 SCI values from known impaired streams, accuracy is determined by the ability to place these streams in a biologically impaired category. Biologically impaired categories are Partially Biological Supporting or Non-Biologically Supporting (scores <16). Of the 31 SCI scores, 28 are <16. Therefore, under these impairment criteria the assessments using the biological criteria in this document are determined to be 90% accurate.

Table 7
Information for Known Impaired Streams

Name of stream	**WBID**	**7Q10 (cfs)**	**303(d)**	**Name of major facility**	**Design Flow (cfs)**	**Actual Flow (cfs)**	**% Effluent Flow**
Little Sac River - Greene Co.	1381	0.0	Fecal Coliform from Springfield NW WWTF	Springfield NW WWTF	16.12	5.69	100.0
Clear Creek - Lawrence Co.	3239	0.0	BOD from Monett WWTF	Monett WWTF	9.30	5.43	100.0
Williams Creek - Lawrence Co.	3172	2.0	---	Mt. Vernon WWTF	5.19	0.78	28.1
Wilsons Creek - Greene Co.	2375	0.1	Unknown Toxicity from Urban NPS	Springfield SW WWTF	65.88	---	99.8
Davis Creek - Lafayette Co.	912	0.0	BOD, Nutrients from Odessa SE WWTF	Odessa SE WWTF	0.58	---	100.0
Post Oak Creek - Johnson Co.	928	0.0	---	Warrensburg NW WWTF	5.60	1.38	100.0
Turkey Creek - Jasper Co.	3216	0.1	BOD, NFR Joplin-Turkey Creek WWTF	Joplin WWTF	23.25	---	99.6
Dry Auglaize Creek - Laclede Co.	1145	0.0	BOD, NFR Lebanon WWTF	Lebanon WWTF	5.43	2.84	100.0
Whetstone Creek - Wright Co.	1505	0.0	BOD from 2 Mountain Grove WWTFs	Mountain Grove WWTF & Lagoon	1.04	1.41	100.0
East Fork Locust Creek - Sullivan Co.	610	0.0	---	Milan WWTF & PSF Meat Packing Plant	2.79	0.91	100.0

BOD = Biological Oxygen Demand; NFR = Non-filterable Residue; WWTF = Wastewater Treatment Facility; WBID = Water Body Identification Number

Table 8
Known Impaired Stream SCI Scores

Name of stream	**SCI Score(s) fall and spring samples**
Little Sac River - Greene Co.	10, 10, 12, 12
Clear Creek - Lawrence Co.	8, 8, 12, 10, 10, 10
Williams Creek - Lawrence Co.	10, 10, 10, 12
Wilsons Creek - Greene Co.	10, 6, 10, 10
Davis Creek - Lafayette Co.	14, 14, 14, 14
Post Oak Creek - Johnson Co.	16, 16
Turkey Creek - Jasper Co.	10
Dry Auglaize Creek - Laclede Co.	6, 10, 8, 12
Whetstone Creek - Wright Co.	12
East Fork Locust Creek - Sullivan Co.	16

Multiple Season Scoring

Another issue concerning biological data from natural conditions is the confidence of assessment results from different time periods. This issue is not simply one of repeatability or accuracy, but more one of assessing the prevalent conditions over time. Neither natural conditions nor human induced conditions are static. Both change over time due to environmental or human induced factors. Because of this inherent variability, the assessment of aquatic biological communities becomes a weight of evidence process.

Data were examined from 156 pairs of Spring and Fall locations that were sampled within one year of each other. Of these data, 42 data sets were from potentially impaired streams and 114 data sets were from biological criteria reference locations. Impaired stream locations changed MSCI categories between seasons 19% (8 sets) of the time, whereas reference streams changed slightly less at 17.5% (20 sets). If 19% is used as the maximum, the data suggest that 81% of the time stream sampling locations were placed into the same impairment category across seasons. It is important to note that many environmental and human induced factors could influence a change of categories over time. Using a weight of evidence process, a location should be assessed 2-3 times over both seasons. If there is no change in the MSCI category or one category predominates, the data should prove to be a reliable assessment of the biological condition.

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APPENDIX A

Missouri Biocriteria Wadeable/Perennial Reference Streams
(Further explanation available on pages 7-9)

Appendix A (Part 1)
Missouri Biocriteria Wadeable/Perennial Reference Streams

Waterbody	County	Downstream Legal	Upstream Legal	11 Digit Hydrologic Unit	Drainage Area (Sq Miles)	Ecological Drainage
Apple Creek	Cape Girardeau/Perry	NW1/4 S3 T33N R11E	W1/2 S29 T34N R11E	07140105130	49	Ozark/MS Tribs btwn MO and OH Rivers
Big Creek	Shannon	N1/2 S36 T30N R4W	E1/2 S12 T30N R4W	11010008030	58	Ozark/Current/Black Drainages
Big Sugar Creek	McDonald	NE1/4 S21 T22N R30W	SE1/4 S1 T21N R30W	11070208050	131	Ozark/Elk/Spring Drainages
Blair Creek	Shannon	NW1/4 S18 T29N R2W	SE1/4 S25 T30N R3W	11010008060	43	Ozark/Current/Black Drainages
Boeuf Creek	Franklin	NW1/4 S30 T44N R3W	SW1/4 S36 T44N R4W	10300200080	95	Ozark/Moreau/Loutre Drainages
Bryant Creek	Douglas	E1/2 S15 T25N R14W	NW1/4 S10 T25N R14W	11010006020	219	Ozark/White Drainage
Bull Creek	Christian/Taney	NE1/4 S3 T24N R21W	SE1/4 S25 T25N R21W	11010003010	111	Ozark/White Drainage
Burris Fork	Moniteau	NW1/4 S28 T44N R15W	NW1/4 S6 T43N R15W	10300102200	76	Ozark/Moreau/Loutre Drainages
Castor River	Madison	S1/2 S16 T33N R8E	NW1/4 S10 T33N R8E	07140107010	40	Ozark/Upper St. Francis/Castor Drainages
Cedar Creek	Cedar	N1/2 S9 T34N R27W	E1/2 S29 T34N R27W	10290106090	114	Ozark/Osage Drainage
Center Creek	Lawrence	NE1/4 S24 T27N R29W	SE1/4 S18 T27N R28W	11070207040	39	Ozark/Elk/Spring Drainages
Deer Creek	Benton	NE1/4 S30 T40N R20W	SE1/4 S31 T40N R20W	10290109040	62	Ozark/Osage Drainage
East Fork Black River	Reynolds	SW1/4 S16 T33N R2E	NE1/4 S8 T33N R2E	11010007030	57	Ozark/Current/Black Drainages
East Fork Crooked River	Ray	SE1/4 S14 T52N R27W	NE1/4 S2 T52N R27W	10300101140	96	Plains/MO Tribs btwn Blue and Lamine
East Fork Grand River	Worth	NW1/4 S13 T65N R31W	N1/2 S32 T66N R30W	10280101060	229	Plains/Grand/Chariton Drainages
Grindstone Creek	Dekalb	NW1/4 S2 T58N R30W	SW1/4 S10 T58N R30W	10280101110	76	Plains/Grand/Chariton Drainages
Heaths Creek	Pettis/Saline	N1/2 S23 T48N R20W	SE1/4 S27 T48N R21W	10300103050	94	Plains/MO Tribs btwn Blue and Lamine
Honey Creek	Nodaway	SW1/4 S25 T65N R34W	N1/2 S12 T65N R34W	10240012050	87	Plains/MO Tribs btwn Nishnabotna and Platte Rivers
Horse Creek	Cedar	N1/2 S2 T34N R28W	SW1/4 S9 T34N R28W	10290106090	173	Ozark/Osage Drainage
Huzzah Creek	Crawford	NE1/4 S18 T36N R2W	SE1/4 S29 T36N R2W	07140102030	124	Ozark/Meramec Drainage
Jacks Fork River	Texas/Shannon	NW1/4 S4 T27N R6W	SE1/4 S35 T28N R7W	11010008040	196	Ozark/Current/Black Drainages
Jones Creek	Jasper	NW1/4 S12 T27N R31W	N1/2 S24 T27N R31W	11070207110	24	Ozark/Elk/Spring Drainages
Little Black River	Ripley	SE1/4 S23 T24N R3E	E1/2 S9 T24N R3E	11010008100	97	Ozark/Current/Black Drainages
Little Drywood Creek	Vernon	SE1/4 S30 T35N R31W	NW1/4 S6 T33N R31W	10290104060	124	Plains/Osage Drainage
Little Fox River	Clark	SE1/4 S24 T66N R9W	SE1/4 S14 T66N R9W	07110001030	83	Plains/MS Tribs btwn Des Moines and MO
Little Maries River	Maries	W1/2 S26 T41N R10W	SW1/4 S34 T41N R10W	10290111030	56	Ozark/Osage Drainage
Little Niangua River	Hickory	S1/2 S35 T38N R20W	NE1/4 S26 T37N R20W	10290110020	148	Ozark/Osage Drainage
Little Piney Creek	Phelps	NE1/4 S31 T36N R8W	NE1/4 S5 T35N R8W	10290203010	98	Ozark/Gasconade Drainage
Little Whitewater River	Cape Girardeau	NE1/4 S16 T32N R10E	NW1/4 S1 T32N R9E	07140107050	40	Ozark/Upper St. Francis/Castor Drainages
Locust Creek	Putnam	NE1/4 S34 T66N R20W	S1/2 S10 T66N R20W	10280103090	71	Plains/Grand/Chariton Drainages
Long Branch Platte River	Nodaway	NE1/4 S29 T62N R34W	SE1/4 S30 T63N R34W	10240012080	49	Plains/MO Tribs btwn Nishnabotna and Platte Rivers
Loutre River	Montgomery	SE1/4 S10 T47N R6W	E1/2 S17 T48N R6W	10300200030	215	Ozark/Moreau/Loutre Drainages
Main Ditch	Dunklin	NE1/4 S8 T19N R10E	S1/2 S20 T20N R10E	08020204040		MS Alluvial Plain/Little Drainage
Maple Slough Ditch	Mississippi	SL 3 & 4 T24N R15E	NW1/4 S34 T25N R15E	08020201030	31	MS Alluvial Plain/Lower MS/St. Johns Bayou
Marble Creek	Madison	E1/2 S21 T32N R5E	E1/2 S24 T32N R4E	08020202030	49	Ozark/Upper St. Francis/Castor Drainages
Marrowbone Creek	Daviess	NE1/4 S8 T58N R27W	SW1/4 S18 T58N R27W	10280101170	75	Plains/Grand/Chariton Drainages
Meramec River	Dent	NW1/4 S11 T35N R5W	SE1/4 S13 T35N R5W	07140102020	176	Ozark/Meramec Drainage
Middle Fabius River	Lewis	E1/2 S4 T61N R8W	NE1/4 S15 T62N R9W	07110002090	376	Plains/MS Tribs btwn Des Moines and MO
Mikes Creek	McDonald	SE1/4 S16 T22N R30W	E1/2 S15 T22N R30W	11070208050	65	Ozark/Elk/Spring Drainages
Mill Creek	Phelps	NW1/4 S28 T37N R9W	NE1/4 S8 T36N R9W	10290203010	45	Ozark/Gasconade Drainage

Appendix A (Part 1)
Missouri Biocriteria Wadeable/Perennial Reference Streams

Waterbody	County	Downstream Legal	Upstream Legal	11 Digit Hydrologic Unit	Drainage Area (Sq Miles)	Ecological Drainage
Moniteau Creek	Cooper	E1/2 S23 T46N R16W	SW1/4 S20 T46N R16W	10300102160	69	Ozark/Moreau/Loutre Drainages
No Creek	Livingston/Grundy	SE1/4 S1 T59N R24W	S1/2 S31 T60N R23W	10280102180	65	Plains/Grand/Chariton Drainages
North Fork River	Douglas	SW1/4 S19 T26N R11W	SE1/4 S12 T26N R12W	11010006010	120	Ozark/White Drainage
North River	Marion	SE1/4 S32 T58N R7W	NW1/4 S15 T58N R8W	07110004010	194	Plains/MS Tribs btwn Des Moines and MO
Petite Saline Creek	Cooper	SE1/4 S12 T48N R16W	W1/2 S15 T48N R16W	10300102090	201	Ozark/Moreau/Loutre Drainages
Pomme De Terre River	Polk	SW1/4 S1 T31N R21W	NE1/4 S16 T31N R20W	10290107010	96	Ozark/Osage Drainage
Richland Creek	Morgan	SE1/4 S28 T44N R18W	NW1/4 S4 T43N R18W	10300103020	38	Plains/MO Tribs btwn Blue and Lamine
River Aux Vases	Ste. Genevieve	SW1/4 S26 T37N R8E	E1/2 S33 T37N R8E	07140105010	48	Ozark/MS Tribs btwn MO and OH Rivers
Saline Creek	Miller	NW1/4 S25 T41N R14W	NW1/4 S23 T41N R14W	10290111020	48	Ozark/Osage Drainage
Saline Creek	Ste. Genevieve	SW1/4 S32 T36N R9E	NE1/4 S35 T36N R8E	07140105030	66	Ozark/MS Tribs btwn MO and OH Rivers
Sinking Creek	Reynolds	NE1/4 S35 T30N R2E	SE1/4 S17 T30N R2E	11010007040	77	Ozark/Current/Black Drainages
Sinking Creek	Shannon	NE1/4 S8 T30N R4W	SE1/4 S32 T31N R4W	11010008030	127	Ozark/Current/Black Drainages
South Fabius River	Marion	SE1/4 S26 T59N R8W	SE1/4 S18 T59N R8W	07110003020	362	Plains/MS Tribs btwn Des Moines and MO
South River	Marion	SW1/4 S21 T58N R5W	NW1/4 S6 T57N R5W	07110004030	45	Plains/MS Tribs btwn Des Moines and MO
Spring Creek	Adair	NE1/4 S30 T63N R16W	N1/2 S14 T63N R17W	10280202010	89	Plains/Grand/Chariton Drainages
Spring Creek	Douglas	NW1/4 S34 T25N R11W	NW1/4 S26 T25N R11W	11010006030	131	Ozark/White Drainage
Tavern Creek	Miller	NW1/4 S33 T39N R12W	NW1/4 S7 T38N R12W	10290111010	59	Ozark/Osage Drainage
Turnback Creek	Lawrence	SE1/4 S12 T29N R26W	C S29 T29N R25W	10290106020	99	Ozark/Osage Drainage
West Fork Big Creek	Harrison	SW1/4 S22 T65N R28W	NE1/4 S15 T65N R28W	10280101150	93	Plains/Grand/Chariton Drainages
West Locust Creek	Sullivan	N1/2 S23 T62N R21W	SW1/4 S3 T62N R21W	10280103090	77	Plains/Grand/Chariton Drainages
West Piney Creek	Texas	SW1/4 S10 T30N R10W	NW1/4 S20 T30N R10W	10290202010	85	Ozark/Gasconade Drainage
White Cloud Creek	Nodaway	SE1/4 S18 T62N R35W	NW1/4 S6 T62N R35W	10240013050	64	Plains/MO Tribs btwn Nishnabotna and Platte Rivers

Appendix A (Part 2) - Missouri Biocriteria Wadeable/Perennial Reference Streams
Land Use [Left Column for each category =11 Digit Hydrologic Unit / Right Column for each category = EDU]

Waterbody	Sampling Regime	Temp. Regime	Urban		Row Crop		Grassland		Glade		Forest		Marsh/Swamp		Water	
Apple Creek	RP	Warm	0	7.8	25.4	14.1	50.1	30.2	0	0	24	44.9	0	0	0.2	2.2
Big Creek	RP	Warm	0	0.1	0	0.4	4	22.8	0.4	0.3	95	75.6	0	0	0	0.2
Big Sugar Creek	RP	Warm	0	1.2	0	5.5	31.2	67.2	0	0	68	25.4	0	0	0	0.2
Blair Creek	RP	Warm	0	0.1	0	0.4	4.4	22.8	0.7	0.3	94	75.6	0	0	0.1	0.2
Boeuf Creek	RP	Warm	0.6	1.9	15.4	20.9	39.3	40.3	0	0	44	35	0	0	0.2	1.5
Bryant Creek	RP	Warm	0	0.9	0.4	0.4	36.7	46.4	1.5	0.9	61	48.8	0	0	0	1.9
Bull Creek	RP	Warm	0	0.9	0.2	0.4	34.9	46.4	0.7	0.9	64	48.8	0	0	0.1	1.9
Burris Fork	RP	Warm	0.4	1.9	16.1	20.9	69.2	40.3	0	0	14	35	0	0	0.2	1.5
Castor River	RP	Warm	0	0.2	0.2	6	19	28.7	0	0	80	63.7	0	0	0	0.8
Cedar Creek	RP	Warm	0	0.3	3.6	1.5	67.7	49.7	0	0.8	28	43.4	0	0	0.1	3.4
Center Creek	RP	Cold	0.3	1.2	2.3	5.5	83.8	67.2	0	0	13	25.4	0	0	0.1	0.2
Deer Creek	RP	Warm	0.1	0.3	0.1	1.5	26.4	49.7	2.9	0.8	64	43.4	0	0	6.2	3.4
East Fork Black River	RP	Warm	0	0.1	0.1	0.4	6.4	22.8	1.7	0.3	90	75.6	0	0	1.3	0.2
East Fork Crooked River	GP	Warm	0	2.4	36.2	41.1	43	38.2	0	0	20	16.3	0.4	0.2	0.2	1.2
East Fork Grand River	GP	Warm	0	0.2	18	30.3	61.5	53	0	0	20	15.2	0	0.1	0.1	0.7
Grindstone Creek	GP	Warm	0	0.2	34.7	30.3	52	53	0	0	12	15.2	0	0.1	0.6	0.7
Heaths Creek	RP	Warm	0	2.4	43.35	41.1	38.55	38.2	0	0	17.5	16.3	0	0.2	0.05	1.2
Honey Creek	GP	Warm	0	0.8	39.2	55.8	49.9	31.9	0	0	10	9.2	0.3	0.6	0.1	1.1
Horse Creek	GP	Warm	0	0.3	3.6	1.5	67.7	49.7	0	0.8	28	43.4	0	0	0.1	3.4
Huzzah Creek	RP	Warm	0	1.4	0.1	1.7	16	28.5	0	0	83	67.1	0	0	0.1	0.5
Jacks Fork River	RP	Warm	0.15	0.1	0	0.4	22.55	22.8	0.45	0.3	76.5	75.6	0	0	0	0.2
Jones Creek	RP	Warm	0.1	1.2	2.2	5.5	78	67.2	0	0	19	25.4	0	0	0	0.2
Little Black River	RP	Warm	0	0.1	1.7	0.4	31.8	22.8	0	0.3	66	75.6	0	0	0.2	0.2
Little Drywood Creek	GP	Warm	0.4	0.5	16.4	23	62.1	54.9	0	0	20	17.9	0	0.3	0.6	2.7
Little Fox River	GP	Warm	0	1.2	29.1	43.5	48.3	35.9	0	0	22	17.1	0.1	0.2	0	1.5
Little Maries River	RP	Warm	0	0.3	0.2	1.5	53	49.7	0	0.8	46	43.4	0	0	0.1	3.4
Little Niangua River	RP	Warm	0	0.3	0.1	1.5	42.9	49.7	2.9	0.8	53	43.4	0	0	0.9	3.4
Little Piney Creek	RP	Cold	0	0.1	0	0.9	31.5	43.1	0	0	68	55	0	0	0.1	0.2
Little Whitewater River	RP	Warm	0	0.2	12.9	6	53.2	28.7	0	0	33	63.7	0	0	0.1	0.8
Locust Creek	GP	Warm	0	0.2	14.1	30.3	69.5	53	0	0	16	15.2	0	0.1	0.1	0.7
Long Branch Platte River	GP	Warm	0.2	0.8	49.5	55.8	41.7	31.9	0	0	7	9.2	0.4	0.6	0.2	1.1
Loutre River	GP	Warm	0	1.9	20.3	20.9	23.3	40.3	0	0	56	35	0	0	0.5	1.5
Main Ditch	GP	Warm	2.3	0.9	81.8	78.3	11	10.9	0	0	4	7.4	0.2	1	0.2	0.9
Maple Slough Ditch	GP	Warm	1.2	0.7	87.7	71	4.1	2.9	0	0	2	5.2	0.7	3	3.8	16.7
Marble Creek	RP	Warm	0	0.2	0	6	12.7	28.7	0	0	86	63.7	0	0	0.3	0.8
Marrowbone Creek	GP	Warm	0.3	0.2	30.2	30.3	56.3	53	0	0	13	15.2	0	0.1	0.1	0.7
Meramec River	RP	Warm	0	1.4	0	1.7	18.3	28.5	0	0	81	67.1	0	0	0.1	0.5
Middle Fabius River	GP	Warm	0.3	1.2	34.3	43.5	46.1	35.9	0	0	19	17.1	0	0.2	0.2	1.5
Mikes Creek	RP	Warm	0	1.2	0	5.5	31.2	67.2	0	0	68	25.4	0	0	0	0.2
Mill Creek	RP	Cold	0	0.1	0	0.9	31.5	43.1	0	0	68	55	0	0	0.1	0.2
Moniteau Creek	RP	Warm	0.1	1.9	17.7	20.9	57.2	40.3	0	0	24	35	0	0	0.2	1.5

Appendix A (Part 2) - Missouri Biocriteria Wadeable/Perennial Reference Streams
Land Use [Left Column for each category =11 Digit Hydrologic Unit / Right Column for each category = EDU]

Waterbody	Sampling Regime	Temp. Regime	Urban		Row Crop		Grassland		Glade		Forest		Marsh/Swamp		Water	
No Creek	GP	Warm	0	0.2	36.7	30.3	51.2	53	0	0	11	15.2	0.1	0.1	0.3	0.7
North Fork River	RP	Warm	0	0.9	0.1	0.4	36.2	46.4	0.8	0.9	62	48.8	0	0	0.1	1.9
North River	GP	Warm	0.6	1.2	41.3	43.5	40.5	35.9	0	0	16	17.1	0	0.2	0.3	1.5
Petite Saline Creek	GP	Warm	0	1.9	31.5	20.9	49	40.3	0	0	19	35	0	0	0.3	1.5
Pomme De Terre River	RP	Warm	0.9	0.3	0.1	1.5	67.5	49.7	0	0.8	31	43.4	0	0	0.1	3.4
Richland Creek	RP	Warm	0.1	2.4	5.9	41.1	54.1	38.2	0	0	39	16.3	0	0.2	0.2	1.2
River Aux Vases	RP	Warm	0	7.8	18	14.1	30.7	30.2	0	0	50	44.9	0	0	0.6	2.2
Saline Creek Miller	RP	Warm	0.1	0.3	1.9	1.5	31.6	49.7	0.4	0.8	64	43.4	0	0	1.3	3.4
Saline Creek Ste	RP	Warm	0	7.8	6.8	14.1	31.8	30.2	0	0	60	44.9	0	0	0.4	2.2
Sinking Creek Reynolds	RP	Warm	0	0.1	0	0.4	11.2	22.8	1	0.3	87	75.6	0	0	0	0.2
Sinking Creek Shannon	RP	Warm	0	0.1	0	0.4	4	22.8	0.4	0.3	95	75.6	0	0	0	0.2
South Fabius River	GP	Warm	0	1.2	38.5	43.5	45.4	35.9	0	0	15	17.1	0.1	0.2	0.2	1.5
South River	RP	Warm	4.3	1.2	39.7	43.5	33.5	35.9	0	0	20	17.1	0.7	0.2	1.1	1.5
Spring Creek Adair	GP	Warm	0.2	0.2	9.8	30.3	55.4	53	0	0	34	15.2	0	0.1	0	0.7
Spring Creek Douglas	RP	Cold	0	0.9	0	0.4	36.4	46.4	0	0.9	63	48.8	0	0	0.1	1.9
Tavern Creek	RP	Warm	0.1	0.3	0.8	1.5	50.1	49.7	0.1	0.8	48	43.4	0	0	0.1	3.4
Turnback Creek	RP	Cold	0	0.3	0.3	1.5	76.3	49.7	0	0.8	23	43.4	0	0	0.4	3.4
West Fork Big Creek	GP	Warm	0	0.2	22.6	30.3	59.7	53	0	0	17	15.2	0	0.1	0.1	0.7
West Locust Creek	GP	Warm	0	0.2	14.1	30.3	69.5	53	0	0	16	15.2	0	0.1	0.1	0.7
West Piney Creek	RP	Warm	0.1	0.1	0	0.9	56.8	43.1	0	0	43	55	0	0	0	0.2
White Cloud Creek	GP	Warm	0.5	0.8	53.6	55.8	39.1	31.9	0	0	6	9.2	0.3	0.6	0.3	1.1

APPENDIX B

Missouri Biocriteria Wadeable/Perennial Streams 25th Percentile and Range Bisection Values
Data Derived from Fall 1994 –Fall 2001

Appendix B - Missouri Biocriteria Wadeable/Perennial Stream 25th Percentile and Range Bisection Values **V4**

EDU	Regime	Samples	Taxa Richness	EPT	Biotic Index	Shan. Index	
Cold Water Streams - Fall Season							
Ozark Region							
Ozark/ Elk / Spring Drainages	RP	4	77	20	5.49	3.2	25th Percentile
RP_F_C_OES			38	10	7.75	1.6	Bisection
Ozark/ Gasconade Drainage	RP	9	82	24	4.94	2.88	25th Percentile
RP_F_C_OG			41	12	7.47	1.44	Bisection
Ozark/ Osage Drainage	RP	3	83	25	5.09	3.3	25th Percentile
RP_F_C_OO			42	12	7.54	1.65	Bisection
Ozark/ White Drainage	RP	9	82	24	4.94	2.88	25th Percentile
RP_F_C_OW			41	12	7.47	1.44	Bisection
Cold Water Streams - Spring Season							
Ozark Region							
Ozark/ Elk / Spring Drainages	RP	3	87	29	5.55	3.45	25th Percentile
RP_S_C_OES			44	14	7.78	1.72	Bisection
Ozark/ Gasconade Drainage	RP	9	84	26	5.4	3.1	25th Percentile
RP_S_C_OG			42	13	7.7	1.55	Bisection
Ozark/ Osage Drainage	RP	4	86	33	5.05	3.45	25th Percentile
RP_S_C_OO			43	17	7.52	1.72	Bisection
Ozark/ White Drainage	RP	9	84	26	5.4	3.1	25th Percentile
RP_S_C_OW			42	13	7.7	1.55	Bisection
Warm Water Streams - Fall Season							
MS Alluvial Plain Region							
MS Alluvial Plain/ Little Drainage	GP	3	53	9	7.07	2.8	25th Percentile
GP_F_W_ML			26	4	8.54	1.4	Bisection
MS Alluvial Plain/ Lower MS / St. Johns Bayou	GP	3	53	9	7.07	2.8	25th Percentile
GP_F_W_MMSSJ			26	4	8.54	1.4	Bisection
MS Alluvial Plain/ White / Black Drainages	GP	3	53	9	7.07	2.8	25th Percentile
GP_F_W_MWB			26	4	8.54	1.4	Bisection
Ozark Region							
Ozark/ Current / Black Drainages	RP	14	84	26	5.13	3.24	25th Percentile
RP_F_W_OCB			42	13	7.57	1.62	Bisection
Ozark/ Elk / Spring Drainages	RP	10	76	22	5.74	2.91	25th Percentile
RP_F_W_OES			38	11	7.87	1.46	Bisection
Ozark/ Gasconade Drainage	RP	19	85	17	6.67	3.23	25th Percentile
RP_F_W_OG			42	8	8.34	1.62	Bisection
Ozark/ MS Tribs btwn MO and OH Rivers	RP	4	80	20	6.27	2.52	25th Percentile
RP_F_W_OMSMO			40	10	8.13	1.26	Bisection
Ozark/ Meramec Drainage	RP	7	78	20	5.86	3.06	25th Percentile
RP_F_W_OM			39	10	7.93	1.53	Bisection
Ozark/ Moreau / Loutre Drainages	GP	4	66	12	7.1	3.08	25th Percentile
GP_F_W_OML			33	6	8.55	1.54	Bisection
Ozark/ Moreau / Loutre Drainages	RP	11	68	13	7.09	3	25th Percentile
RP_F_W_OML			34	6	8.54	1.5	Bisection
Ozark/ Osage Drainage	RP	19	85	17	6.67	3.23	25th Percentile
RP_F_W_OO			42	8	8.34	1.62	Bisection
Ozark/ Upper St. Francis / Castor Drainages	RP	5	81	20	6.14	3.3	25th Percentile
RP_F_W_OUSFC			40	10	8.07	1.65	Bisection
Ozark/ White Drainage	RP	7	79	26	4.79	3.15	25th Percentile
RP_F_W_OW			40	13	7.4	1.58	Bisection
Plains Region							
Plains/ MO Tribs btwn Blue and Lamine Rivers	GP	8	57	6	7.57	2.9	25th Percentile
GP_F_W_PMOBL			28	3	8.78	1.45	Bisection
Plains/ MO Tribs btwn Blue and Lamine Rivers	RP	11	68	13	7.09	3	25th Percentile
RP_F_W_PMOBL			34	6	8.54	1.5	Bisection
Plains/ Grand / Chariton Drainages	GP	14	49	9	7.28	2.67	25th Percentile
GP_F_W_PGC			24	4	8.64	1.34	Bisection
Plains/ Grand / Chariton Drainages	RP	5	54	17	6.83	2.9	25th Percentile
RP_F_W_PGC			27	8	8.42	1.45	Bisection
Plains/ MO Tribs btwn Nishnabotna and Platte Rivers	GP	5	58	8	7.36	3	25th Percentile
GP_F_W_PMONP			29	4	8.68	1.5	Bisection
Plains/ Osage Drainage	GP	8	57	6	7.57	2.9	25th Percentile
GP_F_W_PO			28	3	8.78	1.45	Bisection
Plains/ MS Tribs btwn Des Moines and MO Rivers	GP	5	57	8	7.12	2.88	25th Percentile
GP_F_W_PMSDM			28	4	8.56	1.44	Bisection
Plains/ MS Tribs btwn Des Moines and MO Rivers	RP	7	80	18	6.36	3.06	25th Percentile
RP_F_W_PMSDM			40	9	8.18	1.53	Bisection

Appendix B - Missouri Biocriteria Wadeable/Perennial Stream 25th Percentile and Range Bisection Values V4

EDU	Regime	Samples	Taxa Richness	EPT	Biotic Index	Shan. Index	
Warm Water Streams - Spring Season							
MS Alluvial Plain Region							
MS Alluvial Plain/ Little Drainage	GP	4	51	4	7.9	2.18	25th Percentile
GP_S_W_ML			26	2	8.95	1.09	Bisection
MS Alluvial Plain/ Lower MS / St. Johns Bayou	GP	4	51	4	7.9	2.18	25th Percentile
GP_S_W_MMSSJ			26	2	8.95	1.09	Bisection
MS Alluvial Plain/ White / Black Drainages	GP	4	51	4	7.9	2.18	25th Percentile
GP_S_W_MWB			26	2	8.95	1.09	Bisection
Ozark Region							
Ozark/ Current / Black Drainages	RP	15	89	30	5.41	3.28	25th Percentile
RP_S_W_OCB			44	15	7.7	1.64	Bisection
Ozark/ Elk / Spring Drainages	RP	12	70	26	5.37	2.98	25th Percentile
RP_S_W_OES			35	13	7.68	1.49	Bisection
Ozark/ Gasconade Drainage	RP	29	90	26	6.24	3.2	25th Percentile
RP_S_W_OG			45	13	8.12	1.6	Bisection
Ozark/ MS Tribs btwn MO and OH Rivers	RP	7	89	21	6.62	3.02	25th Percentile
RP_S_W_OMSMO			44	10	8.31	1.51	Bisection
Ozark/ Meramec Drainage	RP	6	90	28	5.9	3.29	25th Percentile
RP_S_W_OM			45	14	7.95	1.65	Bisection
Ozark/ Moreau / Loutre Drainages	GP	4	54	4	7.09	2.72	25th Percentile
GP_S_W_OML			27	2	8.54	1.36	Bisection
Ozark/ Moreau / Loutre Drainages	RP	13	70	13	6.49	2.8	25th Percentile
RP_S_W_OML			35	6	8.24	1.4	Bisection
Ozark/ Osage Drainage	RP	29	90	26	6.24	3.2	25th Percentile
RP_S_W_OO			45	13	8.12	1.6	Bisection
Ozark/ Upper St. Francis / Castor Drainages	RP	8	92	27	5.98	3.26	25th Percentile
RP_S_W_OUSFC			46	14	7.99	1.63	Bisection
Ozark/ White Drainage	RP	8	93	32	4.63	3.23	25th Percentile
RP_S_W_OW			46	16	7.32	1.61	Bisection
Plains Region							
Plains/ MO Tribs btwn Blue and Lamine Rivers	GP	9	50	8	7.32	2.21	25th Percentile
GP_S_W_PMOBL			25	4	8.66	1.1	Bisection
Plains/ MO Tribs btwn Blue and Lamine Rivers	RP	13	70	13	6.49	2.8	25th Percentile
RP_S_W_PMOBL			35	6	8.24	1.4	Bisection
Plains/ Grand / Chariton Drainages	GP	17	48	7	7.24	2.44	25th Percentile
GP_S_W_PGC			24	4	8.62	1.22	Bisection
Plains/ Grand / Chariton Drainages	RP	5	46	11	6.66	2.21	25th Percentile
RP_S_W_PGC			23	6	8.33	1.1	Bisection
Plains/ MO Tribs btwn Nishnabotna and Platte Rivers	GP	5	43	5	7.77	1.94	25th Percentile
GP_S_W_PMONP			22	2	8.88	0.97	Bisection
Plains/ Osage Drainage	GP	9	50	8	7.32	2.21	25th Percentile
GP_S_W_PO			25	4	8.66	1.1	Bisection
Plains/ MS Tribs btwn Des Moines and MO Rivers	GP	8	41	7	7.34	2.01	25th Percentile
GP_S_W_PMSDM			20	4	8.67	1	Bisection
Plains/ MS Tribs btwn Des Moines and MO Rivers	RP	5	74	17	6.31	3.06	25th Percentile
RP_S_W_PMSDM			37	8	8.16	1.53	Bisection